Shoreline Inventory and Assessment of City of Hamilton Owned Assets

City of Hamilton

Final Report

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Executive Summary

The City of Hamilton retained SNC-Lavalin to complete a comprehensive study of the shoreline assets within the City and along the shores of Lake Ontario and Hamilton Harbour.

The shoreline assets consist of a mix of undeveloped lands, storm water outlets, park developments, trail systems, general open spaces, right of ways (ROW), cemetery lands and beaches.

In the spring of 2017, Lake Ontario water levels reached historical levels, exceeding the 100-year design water level of 76.0 m International Great Lakes Datum (IGLD) set by the province. The City of Hamilton also experienced two significant rainfall events accompanied by strong winds from the east. The combination led to flooding and significant erosion or damage, to multiple assets throughout the City.

An in-depth review of the City's existing shorelines and current protection measures was undertaken by the Coastal Engineering team of SNC-Lavalin. The information used for the assessment consisted of:

- Review of existing reports, drawings, and photos provided by the City
- Site visit, by land, on May 25th to 27th, 2019, to visually inspect the accessible and above water portions of the assets.
- Desktop based assessment of the above-water portion of existing slope protection systems using high resolution Unmanned Aerial Vehicle (UAV) point cloud data, orthophotos, and bathymetry sections taken from June 14th to 16th, 2019;
- Estimates of slope and crest elevations based on bathymetry, topography and representative cross-sections of the UAV point cloud data, where visible or not obscured by vegetation, debris, or other structures;
- Metocean analysis to define the extreme conditions (wind and water level) to which the sites are exposed
- Preliminary wave modelling of the Lake during extreme events.

SNC-Lavalin developed conceptual solutions for repair or replacement of existing structures that are not performing well. A few improvements where damage was not observed were also suggested.

This assessment report describes the desktop studies, field investigations, numerical modelling and assessment of the sites of interest. The table below summarizes the site numbers and names used for this assessment and the results of the assessment.

Assessed sites number and name

Site Number	Site Name	Current Conditions
1	Windermere Rd	Poor
2	Fifty Rd Parkette	Not Rated
3	Lake Vista Park	Very Good
4	Wendakee Dr	Fair
5	Winona Rd	Poor / Good
6	Private Road - Excluded	-
7	1137/35 North Services Rd Trillium	Poor
8	Lewis Rd	Poor
9	12 & 14 Trillium Ave	Fair
10	McNeilly Rd	Poor
11	52 Seabreeze Crescent	Poor / Fair
12	Seabreeze Crescent (Easement)	Good
13	Glover Rd	Good / Poor
14	Aquamarine Dr/ Watershore Dr	Good
15	Jones Rd	Not Rated
16	Fruitland Rd	Fair / Very Poor
17	2 Frederick Ave, Frederick Parkette	Fair
18	33 Lakeview Drive (SWM)	Poor
19	497 & 503 Dewitt Rd	Good
20	Cherry Beach	Good
21	1st Private Rd - Excluded	-
22	Millen Rd Parkette	Poor
22B	Green Millen Waterfront Trail	Good / Fair
23	Frances Ave	Poor/ Good / Poor
24	Green Rd	Good
25	Lawrence P. Sayers Park (39 Lakegate Dr)	Good
26	655 Grays Rd	Good / Fair
27	Confederation Beach Park	Various
28	Hamilton Beach	Good
29	Hamilton Harbour Waterfront Trail	Not Rated
29B	Bayfront Park	Various
30	Macassa Bay Marina	Poor
31	Pier 4 Park	Various
32	Desjardins Canal	Not Rated
33	Woodland Cemetery	Not Rated

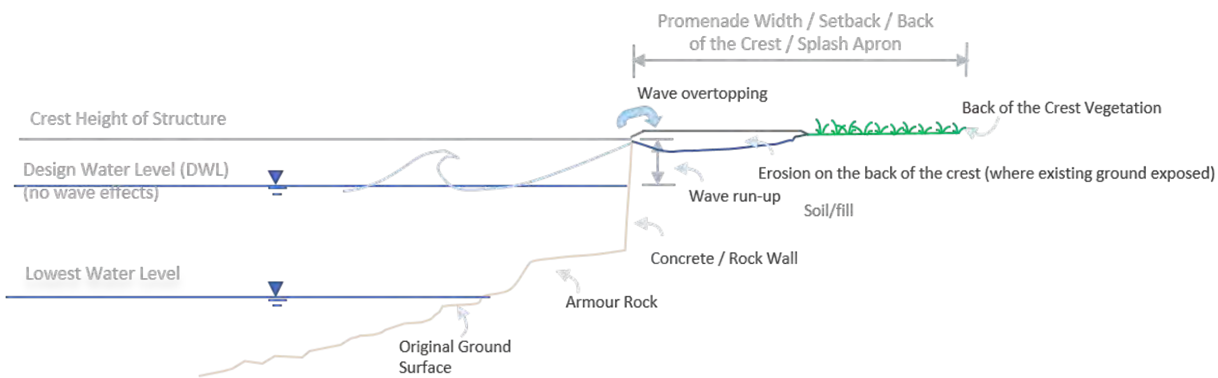
The assessment results are presented by site in Appendix C and descriptions of the impacts of adjacent properties shoreline protection to the City shoreline are included when observable. Each site condition was rated following the rating system created by SNC-Lavalin for shoreline assessments. Sites that were recently protected with a design by a registered Professional Engineer were not rated.

Site 29 (Hamilton Harbour Waterfront Trail – HHWT) was excluded from this assessment as it is currently being assessed in greater detail under a separate assignment/project.

In general, the sites are all exposed to low to moderate volumes of overtopping during extreme events. This exposure to wave overtopping is due to the crest elevation of the shoreline edge and the character of the existing structures, which can significantly increase the wave energy at the shoreline edge and the resulting overtopping volume.

In many cases, the solution for small sites depends considerably on the adjacent properties shoreline character and treatment and how they affect wave conditions in the immediate area. Large sites may not have a single solution. In these cases, it is recommended to create a Shoreline Master Plan to coordinate and prioritize those areas within the large site that warrant rehabilitation. Raising or rearranging pathways might be the most permanent solution for some areas of the large sites with existing low crest elevations and a subsequent potential for flooding.

The figure below shows a sketch of the typical shoreline assessed in this study. The shoreline protection generally consists of a shoreline concrete or rock wall, generally with rock armour protection at the toe of the wall. Wave overtopping is causing erosion of upland, usually unprotected, promenade surfaces because of the low crest elevation and characteristics of the structures.



Typical Shoreline Protection Assessed

Recommendations and suggestions for repairs are given, although a permanent solution needs to be studied in more detail, giving consideration of the City's adjacent land use priorities. The repairs suggested are provisional solutions to avoid further damage on the shoreline and should be final solutions should be detailed and carried out by suitable qualified professional engineers with coastal engineering experience. The potential solutions are described below.

A) Repair: augments or ties into the existing shoreline protection to mitigate damage in relatively localized areas. Two repair solutions are suggested:

A.1) Repair armoured slope

A.2) Repair crest and back of the crest

B) Replacement with rock armour revetment: replaces the existing shoreline protection with a new rock armour revetment design considering updated design criteria (recent water level data and storm events).

C) Replacement with rock armour revetment and headwall: replaces the existing shoreline protection with a new rock armour revetment and concrete headwall design that consider updated design criteria (recent water level data and storm events).

D) Replacement with submerged habitat reef and gravel beach: addition of gravel fill at the beach area and creation of control points (headlands) or submerged habitat reefs.

Repair solutions will restore the structure to its original condition, not necessarily driven by the current water level / wave conditions. Replacement solutions would take into consideration updated design criteria including recent water level data and storms events.

Habitat improvement can be created with any of the options above. Addition of habitat bench, crest vegetation and change in material are some of the improvements suggested for the sites. Habitat improvements of this nature can provide a parallel protection service.

It is highly recommended that monitoring of all sites be undertaken after extreme events during high water level periods. An evaluation regarding the structure conditions and stability would be undertaken during the monitoring after extreme events. The conditions reported in this assessment are from the time of the site visit (May 2019). It is likely that further damage occurred after June / July 2019 due to ongoing high water level periods.

CONTENTS

APPENDICES

1. Glossary

Coastal Structures	Coastal structures include a wide range of works in the coastal zone, including (but not limited to): › Access facilities, such as wharves, piers and boat ramps; › Shoreline protection works, such as seawalls, revetments, and beaches; › Structures to dissipate wave energy or trap sediment, such as breakwaters; › Pipeline, outfalls, and intakes; › Aquaculture related infrastructure; and › Causeways and dikes.
Crest	Highest point on a beach face, breakwater, seawall or wave
Encounter Probability	The probability of a specific event with a defined Annual Exceedance Probability occurring (or being exceeded) in a defined number of years.
“Hard” Engineering Approaches	These approaches include, in general terms: seawalls or revetments, including vertical seawalls, bulkhead systems, rock armour revetments, and conventional sea diking systems.
Metocean Conditions	Meteorological and oceanographic conditions including wind, wave, water level, currents, and other parameters.
Nearshore	The zone extending seaward from the foreshore, or low water line, beyond the area where waves break.
Overtopping	The passage of water over the top of a coastal structure as a result of wave runup and related surge and local setup. The water may pass as a flow of water or as spray. The characteristics of overtopping are site, structure and wave specific.
Revetment	Protective material laid on slopes, generally constructed of durable stone or other material.
Rip-Rap	Slope protection system consisting of a wide gradation of rock material placed in bulk. Rip-rap tends to have smaller voids due to the wide gradation and can result in higher wave run-up.
Rock Armour	Shoreline protection system consisting of armour stones with a narrower gradation than rip-rap, individually placed, commonly with two or three layers. Generally placed overtop of under layer materials, which provide both energy dissipation service and filter action for fill or in-situ materials.
ROW	Right of Way, the legal right established by usage or grant to pass along a specific route through grounds or property belonging to another
Still Water Level	The water level that exists in the absence of waves or wind action.
“Soft” Engineering Approaches	These engineering approaches include, in general terms: beach nourishment, foreshore restoration or construction, dune and wetland construction, shore vegetation preservation or restoration, and nearshore reef and berm construction.

Storm Surge	A change in water level caused by the action of wind and atmospheric pressure variation on the sea surface.
T_P - Peak Wave Period	The inverse of the frequency at which a wave energy spectrum reaches its maximum.
Wave Effects	A general term including all aspects of wave interaction with a coastal structure including: wave setup, wave run-up and overtopping.
Wave run-up	Vertical distance that water runs up the shoreline/structure slope due to waves during the designated storm.

2. Introduction

This report presents the methodology undertaken to complete a comprehensive study of the City owned shoreline assets within the City along the shores of Lake Ontario and Hamilton Harbour, including conclusions / recommendations of the assessed shorelines.

In the spring of 2017, Lake Ontario water levels reached historical levels, exceeding the 100-year design water level of 76.0 m (IGLD) set in 2011. The City of Hamilton also experienced two significant rainfall events accompanied by strong winds from east. The combination led to flooding and significant erosion to multiple assets throughout the City. In the spring of 2019, the water levels were again close to reaching historical levels. Fortunately, winds were not as strong as in 2017. There was still flooding in a few of the City's properties.

An in-depth review of the City's existing shorelines and current protection measures were undertaken by the Coastal Engineering team of SNC-Lavalin.

The current conditions of the shoreline was assessed by the site visit and field investigations, and the potential damage was estimated for the effects of extreme events. Data analysis of historical metocean (wind and water level) conditions was undertaken to understand the impacts on the shoreline, and numerical modelling was used to define extreme wave events.

This report is structured to present the metocean conditions, a summary of the assessment and potential solutions in the main document. Details of the assessment by site is presented in Appendix C.

Section 3 describes the site metocean conditions by analysing the existing historical data and using a numerical wave model to define the wave impact on the shoreline.

Section 4 presents the assessment methodology following a rating system created by SNC-Lavalin for shoreline assessments.

Section 5 presents the site description and potential solutions to reduce shoreline erosion. Impacts of adjacent properties shoreline protection to the City shoreline were included when observable.

Details of the extreme water levels considered are provided in Appendix A. Details of the survey methods are presented in Appendix B.

Appendix C presents the shoreline assessment for each site with a photo inventory. Appendix D and E presents the condition rating mapping and high resolution orthomosaic photos for each assessed site, respectively.

3. Metocean Conditions

The metocean conditions driving the shoreline erosion at the City of Hamilton are winds, water levels and waves. An initial analysis of the metocean conditions at the site was conducted to quantify the impact on the shoreline. Wind and water level data were acquired from publicly available sources. Extreme design waves were modelled based on extreme wind events occurring simultaneously as the design water level.

Elevations reported in this assessment are referenced to International Great Lakes Datum 1985 (IGLD), Chart Datum is 74.2 m IGLD.

3.1 Water Level

Water level information was acquired from Environmental Canada from the stations Toronto, Burlington and Port Weller as shown in Figure 1. The exact coordinates of the stations and the period of available data are summarized in Table 1.

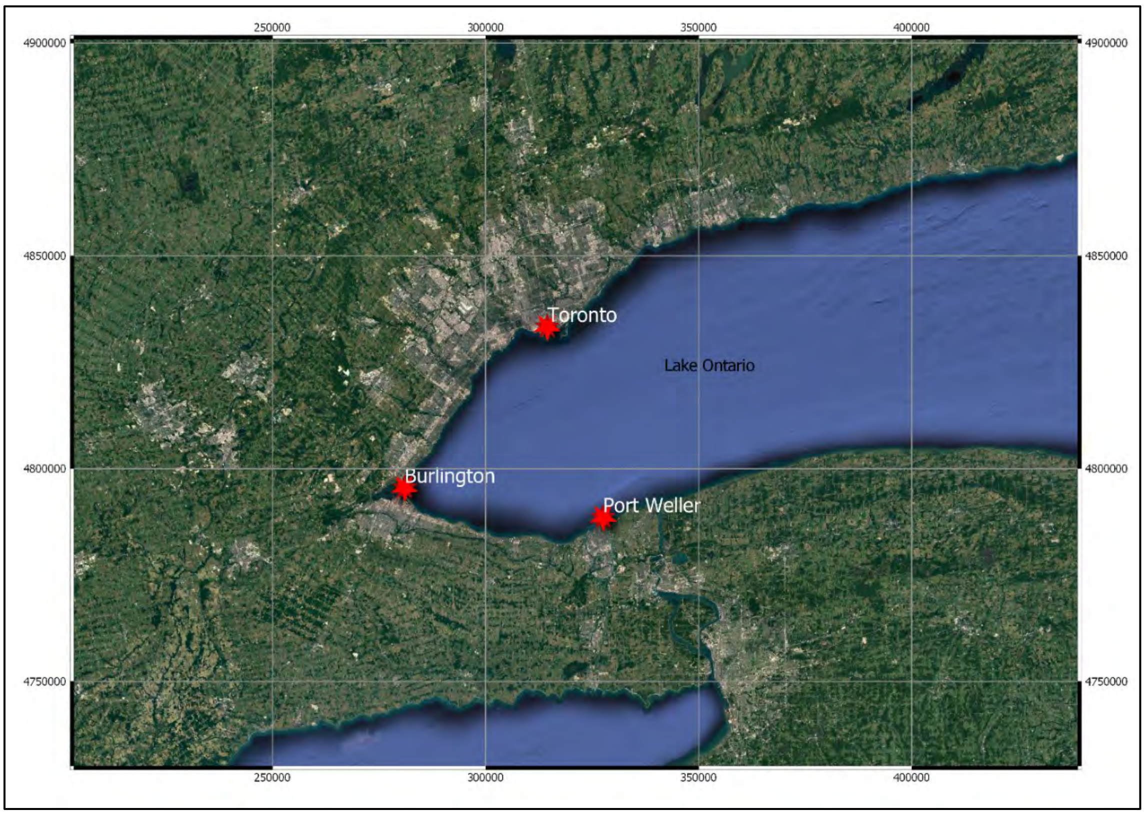


Figure 1: Location of Water Level Stations

Table 1 Information of Water Level Stations

Station Name	Climate ID	Location (UTM Easting/Northing)	Period of Measurements
Burlington	13150	402133.4/4794774.4	2009-2019
Port Weller	13030	355442.5/4788640.7	1962-2019
Toronto	13320	369356.9/4833138.8	1962-2019

3.1.1 Maximum Water Levels

A comparison between annual maximum water levels, measured at the stations for the last 11 years (period of concurrent measurements), is shown in Figure 2. Appendix A presents a comparison of the entire time series (1962-2019).

The Burlington Station is the closest to the sites of interest; however, the measured time series for this station only starts in 2009.

A Gumbel distribution function for extreme value analysis of the water level records was performed following the methodology described in Goda (Ref. [7]).

An extreme value analysis was conducted for each data set and the results are summarized in Table 2. The extreme value analysis results are more reliable at the Toronto and Port Weller Stations because they were active for almost 58 years.

Even though the records for the year of 2019 were not complete (archived and available up to June 2nd at the time of this analysis), all the available data was considered in the analysis because it included another historical high water level.

The maximum water level of 76.04 m was registered at Port Weller station in 2017.

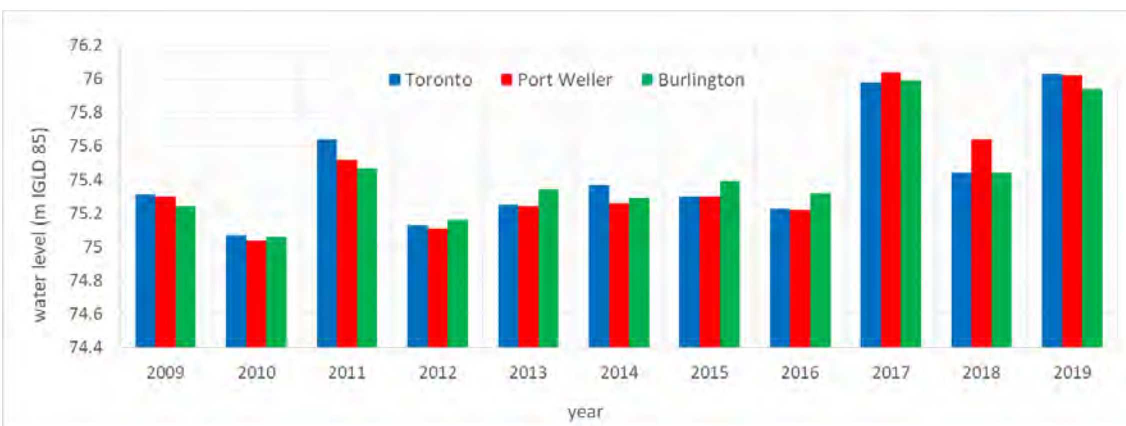


Figure 2: Historical maximum measured water level

Table 2 Extreme Water Levels – (including 95% Confidence Limits)
Fitted distribution - Gumbel (EV1)

Return Period (years)	Extreme Water Level Analysis (m IGLD)		
	Port Weller	Toronto	Burlington
10	75.7 (75.5 to 75.9)	75.6 (75.5 to 75.8)	75.8 (75.4 to 76.2)
25	75.9 (75.7 to 76.1)	75.8 (75.6 to 76.0)	76.1 (75.5 to 76.6)
50	76.1 (75.8 to 76.3)	75.9 (75.7 to 76.2)	76.2 (75.5 to 76.9)*
100	76.3 (76.0 to 76.6)	76.1 (75.8 to 76.3)	76.4 (75.6 to 77.2)*

* shorter time series

The 100-year flood level at 76.0 m at the Lake Ontario Shoreline is reflected[1] in the 2011 guidelines from the Hamilton Conservation Authority (Ref.[1]).

An analysis of the extreme value results showed that the 2017 high water level was very close to being an outlier (unusually high) compared to the overall 58 year data record. This high-water level might be the result of recent changes to the Great Lakes water regime – possible related to climate change driven effects. Extreme value analysis of the last 20 years of record, regardless of which water level station is used, indicates that the 1:100 year water level should be considered to be 76.4 m (IGLD), suggesting that the 2011 guidelines recommendation (1:100) year water level of 76.0 m should be expected much more frequently than it was in the past.

It is recommended an in depth analysis of the extreme water levels before defining the design still water level at the detailed design stage.

3.1.2 Minimum Water Levels

A comparison between annual minimum water levels, measured at the stations for the last 11 years (period of concurrent measurements), is shown in Figure 3. Appendix A presents a comparison of the entire time series (1962-2019).

For the purpose of concept evaluations and options development, the minimum water level considered was 73.62 m (IGLD), based on the lowest measurement at Toronto station in 1965. During the last 11 years, the minimum water level was recorded at Burlington in 2012, 74.12 m (IGLD).

[1] The 100-year flood level was set by the province and incorporated into HCA's regulation in 2006

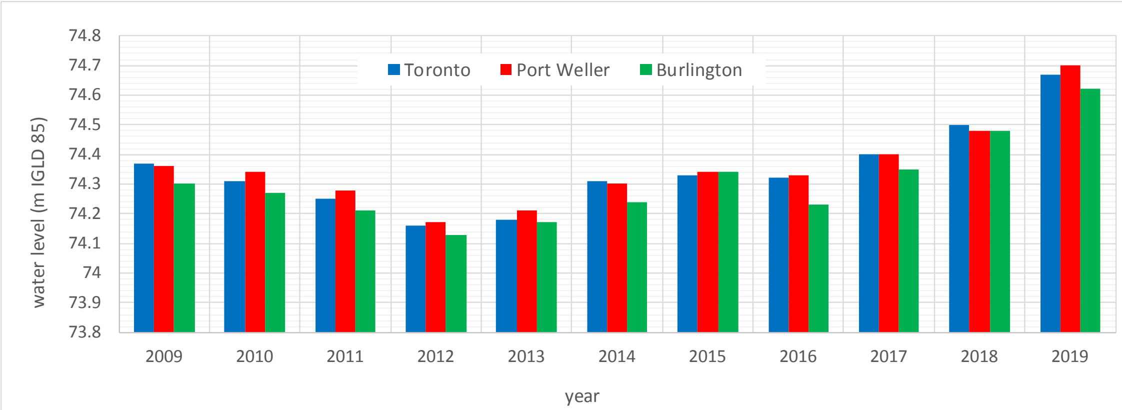


Figure 3: Historical minimum measured water level

3.2 Wind

The wind data for this study was acquired from Environmental Canada for four stations: Hamilton A, Burlington Piers, C45139 (West Lake Ontario) and C45159 (Figure 4). C45159 was not considered in the analysis because it only consists of two years of data measurement. Table 3 shows the climate IDs, locations, and period of measurements for the available data. The wind data considered for this study covers the period from 1970 to 2018. Station Hamilton A[1], at the Hamilton Airport, was slightly relocated to Hamilton A[2]. These stations are considered as one station (Hamilton A) for analysis.

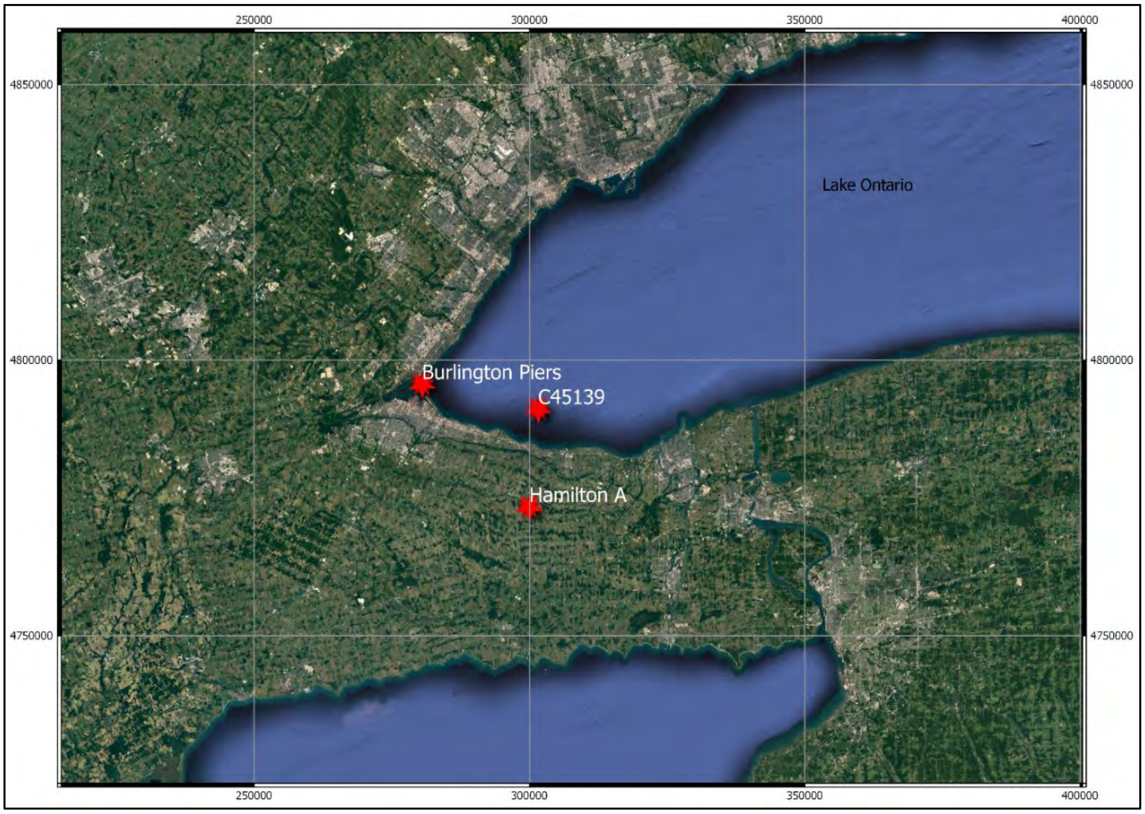


Figure 4: Location of Wind Stations

Table 3 Information of Wind Stations

Station Name	Station/Climate ID	Location (UTM Easting/Northing)	Period
Hamilton A[1]	6153194	499435.7/47881155286.0	1970-2011
Hamilton A[2]	6153193	586637.0/47881926279.7	2011-2018
Burlington Piers	6151061	395390.6/47968024004.0	1995-2018
West Lake Ontario	C45139	618500.0/ 4790722.8	1997-2018

Hamilton A

The wind rose and bivariate histogram for Hamilton A are presented in Table 4 and Figure 5. The most frequent winds and the highest wind speeds are from the west. The maximum wind speed registered during the past 48 years (1970-2018) was approximately 31 m/s and calm conditions occurred in approximately 3% of the records.

Table 4 Bivariate histogram wind speed and direction Hamilton Airport Station (1970-2018)

	UDir (from deg T)																
U (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
>20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
15.0 - 20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0%
10.0 - 15.0	0.0%	0.1%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.7%	1.0%	0.7%	0.2%	0.1%	0.0%	4%
5.0 - 10.0	1.0%	1.4%	3.3%	3.3%	0.7%	0.1%	0.1%	0.2%	1.4%	3.3%	4.5%	5.4%	5.1%	2.6%	1.8%	0.9%	35%
0.0 - 5.0	3.0%	3.0%	4.8%	4.4%	3.0%	1.0%	0.9%	1.4%	4.0%	4.6%	5.6%	6.1%	7.4%	3.4%	2.6%	2.0%	57%
< 0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Calm																	3%
Total	4.0%	4.6%	8.5%	8.3%	3.7%	1.1%	1.0%	1.6%	5.4%	8.1%	10.9%	12.7%	13.2%	6.2%	4.5%	3.0%	100%

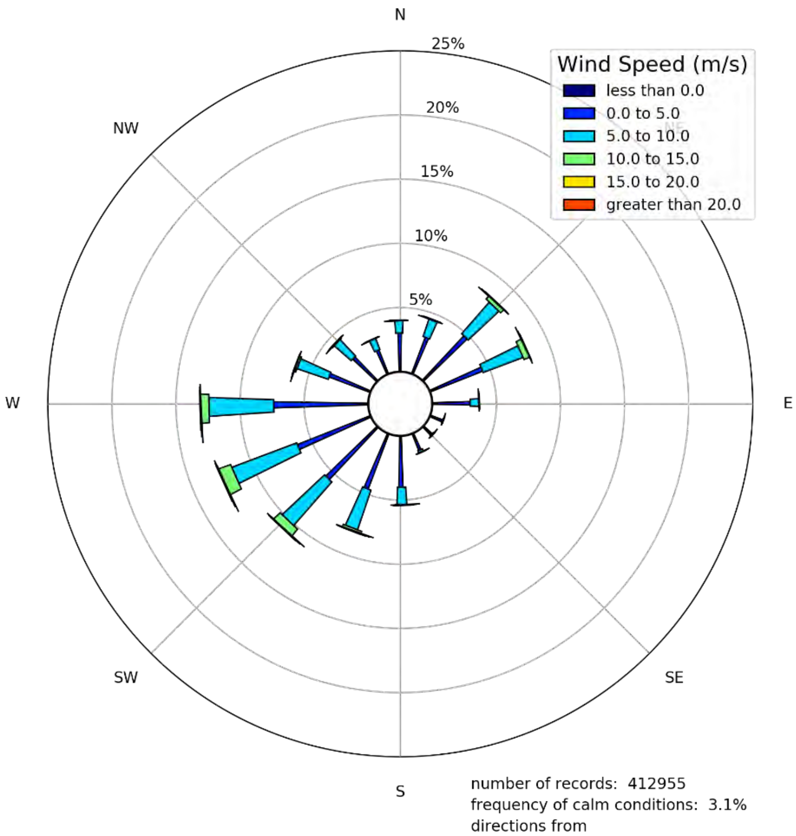


Figure 5 Wind Rose from Hamilton Airport Station (1970-2018)

Burlington Piers

The results for Burlington Piers are similar to Hamilton A and show that the most frequent winds and highest wind speeds are also from the west. The maximum wind speed registered during the analysed period of 23 years was approximately 18 m/s, while calm conditions occurred in only 1.4% of the records.

Table 5 Bivariate histogram wind speed and direction Burlington Piers Station (1995-2018)

	UDir (from deg T)																
U (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
>20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.0 - 20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
10.0 - 15.0	0.1%	0.1%	0.5%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%
5.0 - 10.0	2.6%	1.3%	2.6%	0.8%	1.6%	0.2%	0.3%	0.2%	1.8%	1.8%	2.5%	1.2%	2.3%	1.5%	1.9%	1.2%	23.7%
0.0 - 5.0	5.4%	2.9%	4.8%	2.2%	4.7%	1.6%	2.0%	0.8%	2.4%	3.7%	10.4%	10.2%	13.0%	3.4%	3.5%	2.3%	73.4%
<0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Calm																	1.4%
Total	8.2%	4.4%	8.0%	3.3%	6.5%	1.8%	2.3%	1.0%	4.2%	5.6%	12.8%	11.3%	15.3%	4.9%	5.4%	3.5%	100.0%

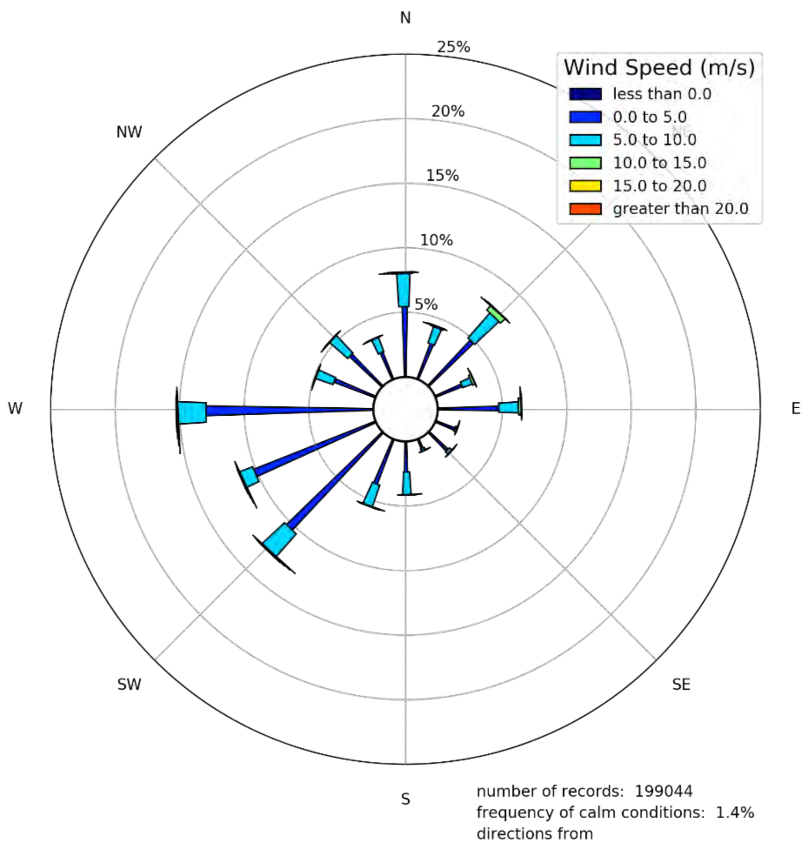


Figure 6 Wind Rose from Burlington Piers Station (1995-2018)

<u>C45139 Station (West Lake Ontario)</u>

As it can be seen in the bivariate histogram for station C45139 (Table 6) and the wind rose (Figure 7), the most frequent winds and the highest wind speeds at the overwater station are from the east. Approximately 56% of the winds have speeds of less than 5 m/s. The maximum wind speed registered during the past 21 years (1997-2018) was approximately 22.5 m/s. Calm conditions have occurred in 2% of the records.

Table 6 Bivariate histogram wind speed and direction C45139 Station (1997-2018)

	UDir (from deg T)																
U (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
>20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.0 - 20.0	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.6%
10.0 - 15.0	0.2%	0.1%	0.2%	0.3%	0.7%	0.2%	0.0%	0.1%	0.3%	0.6%	0.6%	0.8%	0.9%	0.5%	0.4%	0.3%	6.2%
5.0 - 10.0	1.7%	1.1%	1.7%	2.5%	2.6%	1.3%	0.6%	1.2%	2.0%	3.0%	3.5%	3.0%	2.9%	2.4%	1.8%	1.3%	32.6%
0.0 - 5.0	3.0%	3.2%	4.6%	5.0%	5.3%	4.1%	3.2%	2.8%	3.1%	3.3%	3.7%	4.2%	4.3%	3.2%	3.0%	2.6%	58.6%
<0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Calm																	1.9%
Total	5.0%	4.4%	6.5%	7.8%	8.6%	5.6%	3.9%	4.1%	5.4%	7.1%	7.9%	8.1%	8.2%	6.2%	5.2%	4.1%	100.0%

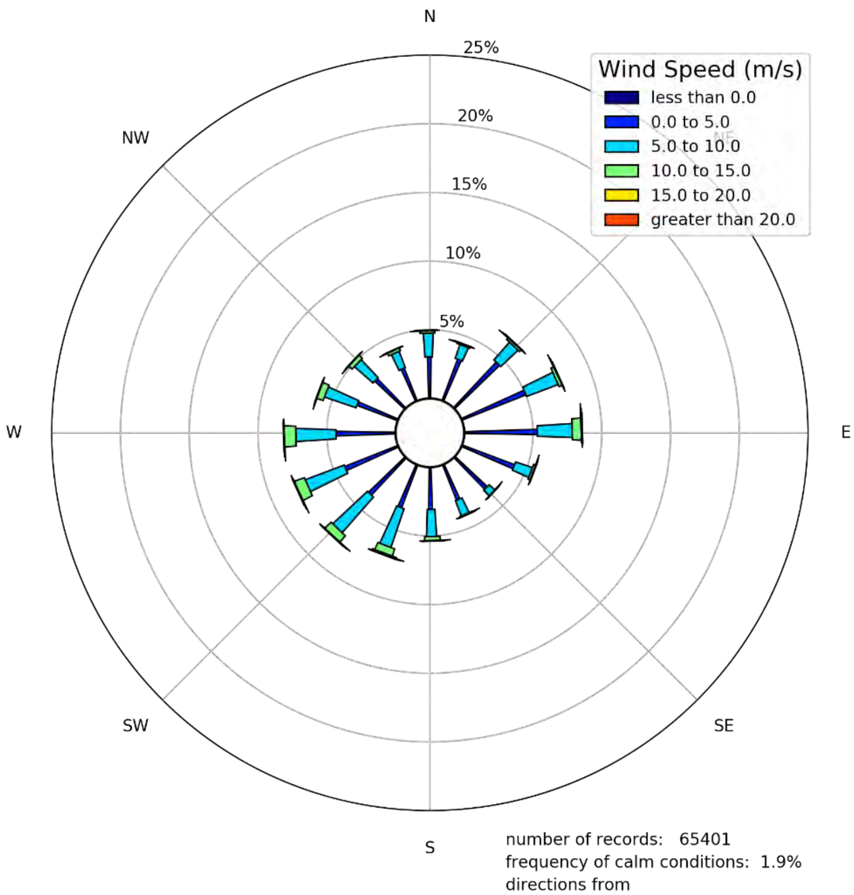


Figure 7 Wind Rose from C45139 Station (1997-2018)

Hamilton A station was selected for extreme wind analysis as the most representative station since the period of measurement is longer than the other stations, which increases the reliability of the results. Existing and anticipated extreme event scenarios were defined to assess the shoreline exposure.

The results of an extreme value analysis are summarized in Table 7.

Table 7 Extreme Wind Speed for Hamilton A Station by Direction (Gumbel)

Hamilton A					
Return Period	**N**	**NE**	**NW**	**E**	**SE**
10	14.8 (13.7 to 15.9)	20.2 (18.4 to 21.9)	15.9 (15.0 to 16.9)	16.7 (15.5 to 17.9)	1.8 (9.8 to 11.9)
25	16.2 (14.7 to 17.7)	22.4 (20.0 to 24.7)	17.2 (15.9 to 18.5)	18.2 (16.6 to 19.7)	12.2 (10.8 to 13.5)
50	17.3 (15.5 to 19.1)	24.0 (21.2 to 26.8)	18.2 (16.6 to 19.7)	19.2 (17.4 to 21.1)	13.1 (11.5 to 14.8)
100	18.4 (16.3 to 20.4)	25.6 (22.3 to 28.8)	19.1 (17.3 to 20.9)	20.3 (18.1 to 22.5)	14.1 (12.2 to 16.1)

It is unusual that an inland station (Hamilton A) measures higher wind speeds than a theoretically more exposed coastal station (Burlington Piers) or an overwater station (C45139). This apparent discrepancy should be investigation in more detail prior to any detailed design of shoreline remedial or upgrading solutions.

3.3 Waves

The wind wave modelling was completed in CMS-Wave [Aquaveo]. The methodology, the bathymetry used in the model, interpolation of the grids, inputs and limitations are described below.

3.3.1 Bathymetry

The bathymetry used for the generation and propagation of the waves was a combination of three sets of data:

1. A large-scale grid (90mx60m) from NOAA to define the entire lake,
2. Data from CHS Chart 2077 for finer resolution of the nearshore bathymetry, with isobaths every 10m, and
3. Local survey data (bathymetry transects) to give a better local resolution at the sites of interest. Further details are provided in Appendix B - Field Survey.

The three sets of data overlapped in some areas. The overlap areas have been checked so that the bathymetry transition was smooth between the different source areas. If the data did not fit, they were removed from the less to the more reliable sets. The survey data was considered as the most accurate followed by the digitised information from the nautical chart and then the NOAA data (coarser grid). All vertical elevations were corrected to Chart Datum.

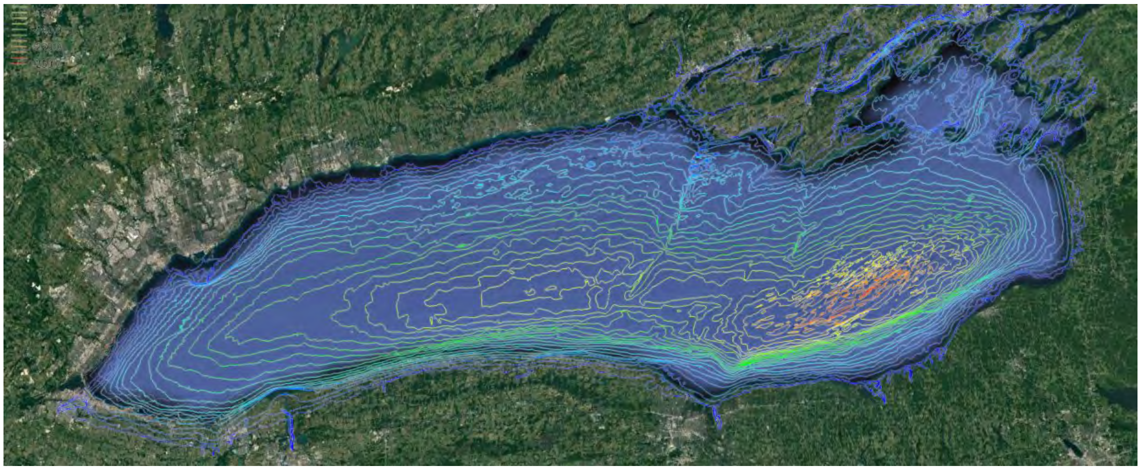


Figure 8 NOAA: Large-scale Grid (90x60m)

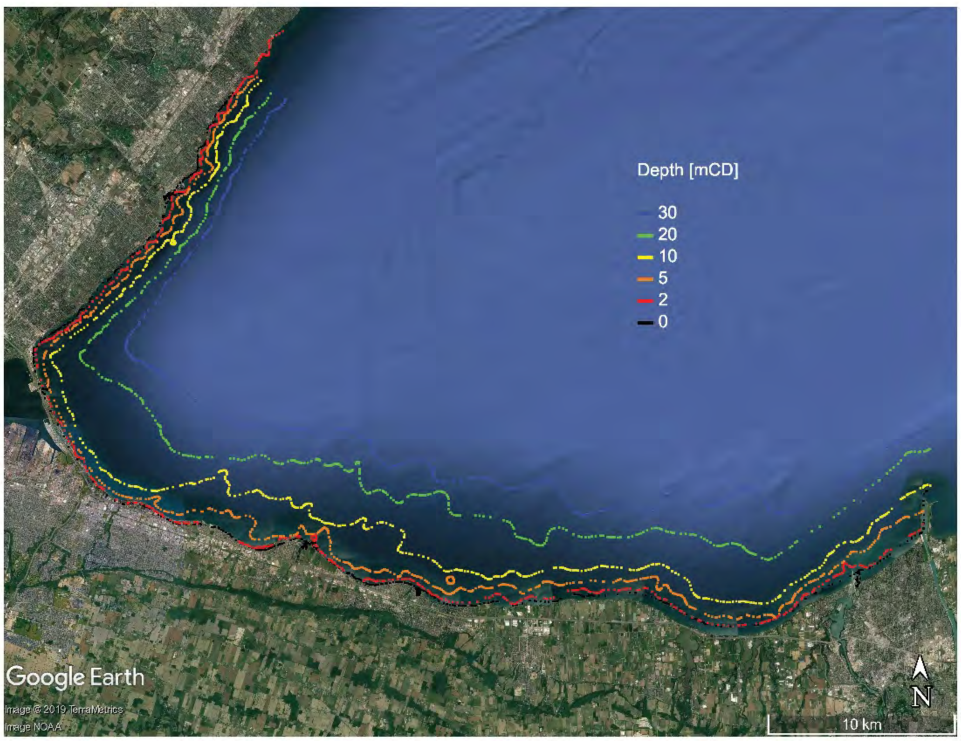


Figure 9 Isobaths (contours) from CHS Chart 2077

3.3.2 Model Grid

The initial bathymetry model was interpolated over a uniform grid for use in the wind/wave generation and propagation model. Three grids (one coarse grid and two fine grids) were generated from the interpolated bathymetry model.

Coarse grid (resolution 150 x 150 m): A coarse grid was created for the entire Lake Ontario. This grid was used to generate the input for wave conditions in the areas of interest. Seven nesting cells were positioned along the smaller west bay open boundary (Figure 10).

Stationary extreme wind conditions from NE, E and SE (Figure 11) were used with the coarse grid to define boundary condition wave climate results.

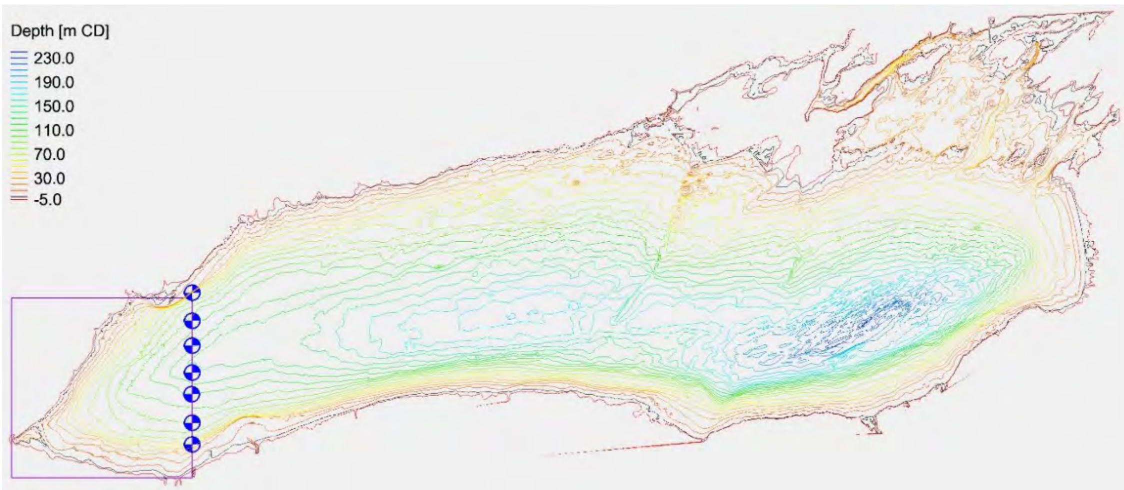


Figure 10 Coarse Grid - Resolution 150x150 m
(inset box shows the Hamilton Fine Grid area)

Hamilton Fine Grid (resolution 20 x 20m): A fine grid was defined at the west end of Lake Ontario (Figure 10 and Figure 11).

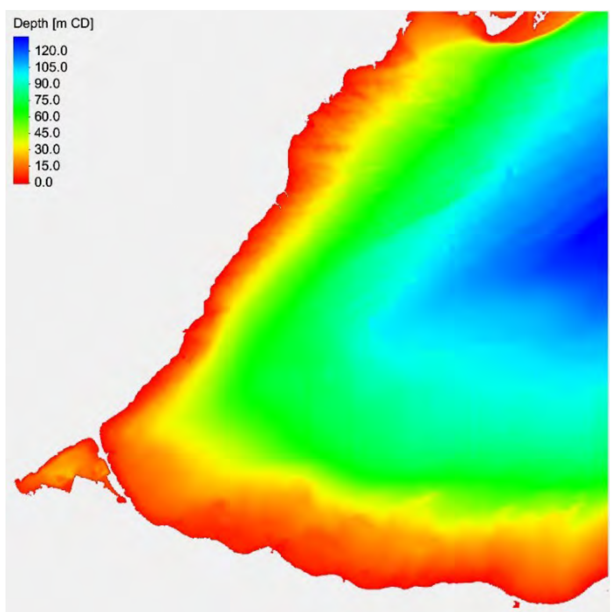


Figure 11 Hamilton Fine Grid (Resolution 20x20m)

Hamilton Harbour Fine Grid (resolution 20 x 20 m): A second fine grid was generated for the Hamilton Harbour area. As this area is essentially separated from Lake Ontario, connected only by the canal, the model used a different grid to generate waves inside the bay for the relevant winds and fetches.

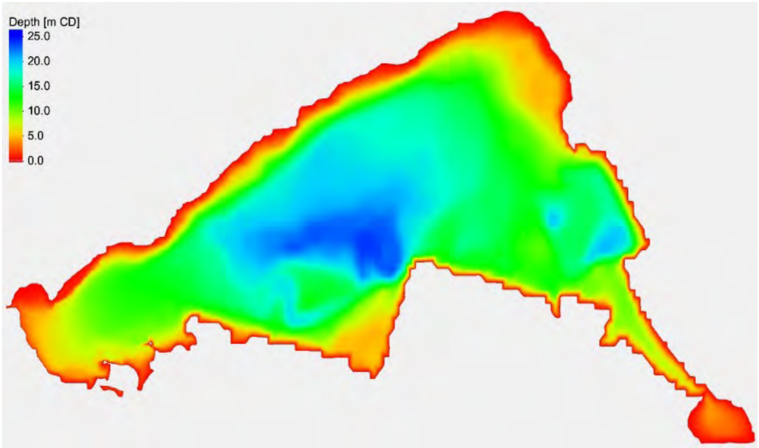


Figure 12 Hamilton Harbour Fine Grid (20x20m)

3.3.3 Inputs

Five cases were considered according to the extreme value analysis described in Section 3.2. The water level conditions correspond to the design water level recommended by Ref. [1]. Table 8 shows the run cases and their respectively wind speed, direction, and water level. The water level used was 74.2 m IGLD, equivalent to 1.8 m CD.

Table 8 Extreme Wind Speed, Direction and Water Level

Run Case #	RUN Cases	Extreme Wind Speed (m/s)	Extreme Wind Direction	Water Level Condition [m CD]
1	Run-NW19	19.0	Northwest	1.8
2	Run-N20	20.0	North	1.8
3	Run-NE26	26.0	Northeast	1.8
4	Run-E20	20.0	East	1.8
5	Run-SE14	14.0	Southeast	1.8

Hamilton Fine Grid inputs

Input for the Hamilton Fine Grid consisted of wind and waves from NE to SE (open boundary); wave conditions were input from the coarse grid model at the east open boundary. For stationary wind runs from NW and N, a constant wind speed was defined over the model grid.

Table 9 Hamilton Fine Grid Inputs Conditions for Each Model Run

	Coarse Grid			Hamilton Fine Grid			Bay Fine Grid		
Run Case #	WL	Wind	Wave	WL	Wind	Wave	WL	Wind	Wave
1	N/A	N/A	N/A	X	X		X	X	
2	N/A	N/A	N/A.	X	X		X	X	
3	X	X		X	X	X	X	X	
4	X	X		X	X	X	X	X	
5	X	X		X	X	X	X	X	

Hamilton Harbour Fine grid inputs

As there is no wave propagation from Lake Ontario to the Bay, the only input used in the Hamilton Bay model were the relevant wind conditions.

3.3.4 Results

Model outputs include the characteristic sea state parameters: significant wave height (Hs), peak period (Tp) and mean wave direction (Dir) over the grid. For each scenario, those characteristics were extracted at specific locations for individual site characterization. The significant wave height and direction results for the worst case (NE) are presented in Figure 13.

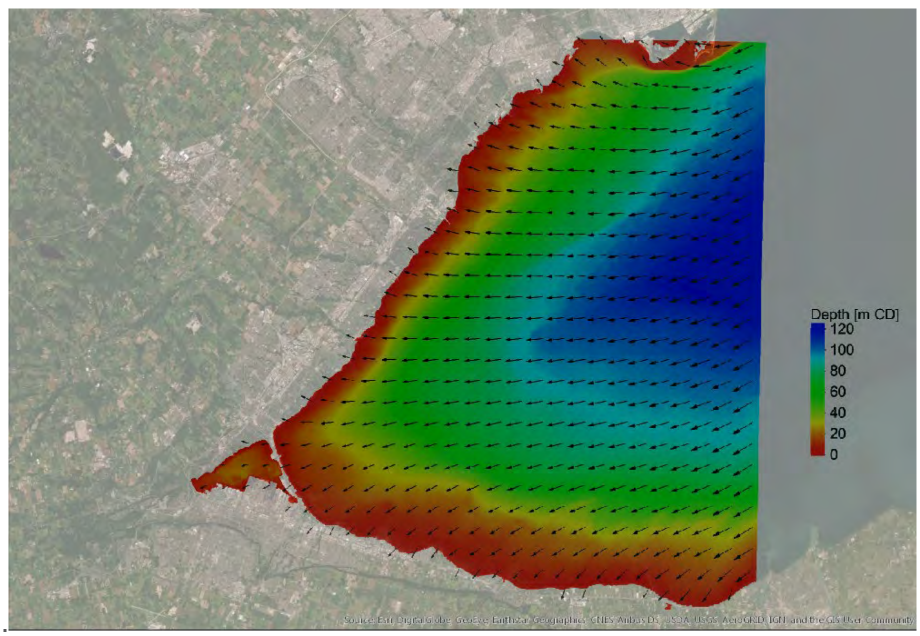


Figure 13 Wave Characteristics Outputs for the NE Run

Post-processing showed that for sites 1-26, the maximum significant wave height was from a wind speed of 26 m/s and direction northeast (Run-NE26). Run-NE26 is an extreme wind event with an Annual Exceedance Probability (AEP) of 1/100. The maximum significant wave height generated by the wind storm was approximately 1.8 m with wave period of 9.1s and wave direction 252 degrees (TN). Table 10 below summarizes the maximum significant wave height, peak wave period and mean wave direction results for each run.

Table 10 Extreme Wave Height, Wave Period and Wave Direction AEP = 1/100

RUN Cases	Wave Height (m) H_s	Wave Period (s) T_p	Wave Direction (deg)
Run-N20	1.1	3.2	297
Run-NE26	**1.8**	**9.1**	**252**
Run-NW19	1.4	3.9	313
Run-E20	1.5	9.1	240
Run-SE14	0.4	2.5	230

3.3.5 Model limitations

The wind scenarios are based on data from Hamilton Airport, which is about 15 km inland. It was chosen because the time series was long enough to develop a reliable statistical analysis. However, the reported and archived winds may be influenced by local conditions.

The model runs, which consider wind to be uniform over the entire Lake Ontario area, may overestimate the wave climate along the City of Hamilton shoreline. A more detailed spatial varying wind model for Lake Ontario may provide less severe results.

Finally, CMS-Wave is a spectral phase-averaged wave model, which was developed for coastal modeling. Wave reflection and diffraction considerations near shoreline structures, where detailed bathymetry warrants, may justify a more detailed phase-resolved wave model, however a phase resolving model requires greater computational effort (and cost) and is not essential for this assessment. A phase-resolving model may be justified during detailed design of any options.

3.3.6 Wave Effects

In general terms, wave effects include wave run-up on the shoreline or wave overtopping on shoreline features. Wave effects can result in flooding, depending on the elevation of land adjacent to or upland of the shoreline and the details of the shoreline structures.

Wave run-up is the vertical distance that water runs up the shoreline/structure slope during the designated storm. Wave overtopping is the volume of water that travels over the structure crest and can range from a small amount of spray to a large volume, capable of damaging structures or flooding the land. Wave overtopping can be quantified by an average discharge rate, q, in L/m/s (litres per metre of shoreline per second). The average rate of overtopping is restricted by the crest elevation of the shoreline structure. It is noted that actual overtopping will occur in individual wave related pulses of water, which, averaged over time, will equal the average discharge rate.

The wave effects were estimated for each site based on the site specific bathymetry, topography and aerophotogrammetry surveys. Assumptions were considered to complete the profile in a few sites.

4. Shoreline Assessment

This shoreline assessment consists of a description of the site and the current shoreline protection system design and condition, including: estimate of crest elevation and slope, a related estimate of wave effects and our evaluation of the current condition or stability and any proposed solution(s).

The results of this assessment are a site condition rating and potential solutions to minimize shoreline damage.

Most of the assessed sites have a short shoreline length and their effectiveness may depend on the adjacent property shoreline performance and conditions. In most cases, it is recommended to extend the protection at these sites and to work with the neighbouring properties to optimize the performance of the area specific protection systems.

The assessment methodology considered the following information:

- Review of construction drawings and past inspection reports, if available and relevant;
- Site visit by land on May 25th to 27th, 2019 to visually inspect the above water portions of the assets.
- Desktop condition assessment of above-water portion of slope protection using high resolution UAV point cloud data (see Figure 1 and Figure 2), orthophotos, and bathymetry sections taken from June 14th to 16th, 2019;
- Estimates of slope and crest elevation based on bathymetry, topography and representative cross-sections of the UAV point cloud data, where visible and not obscured by vegetation, debris, or other structures;

Figure 14 Example of UAV data with excellent visibility

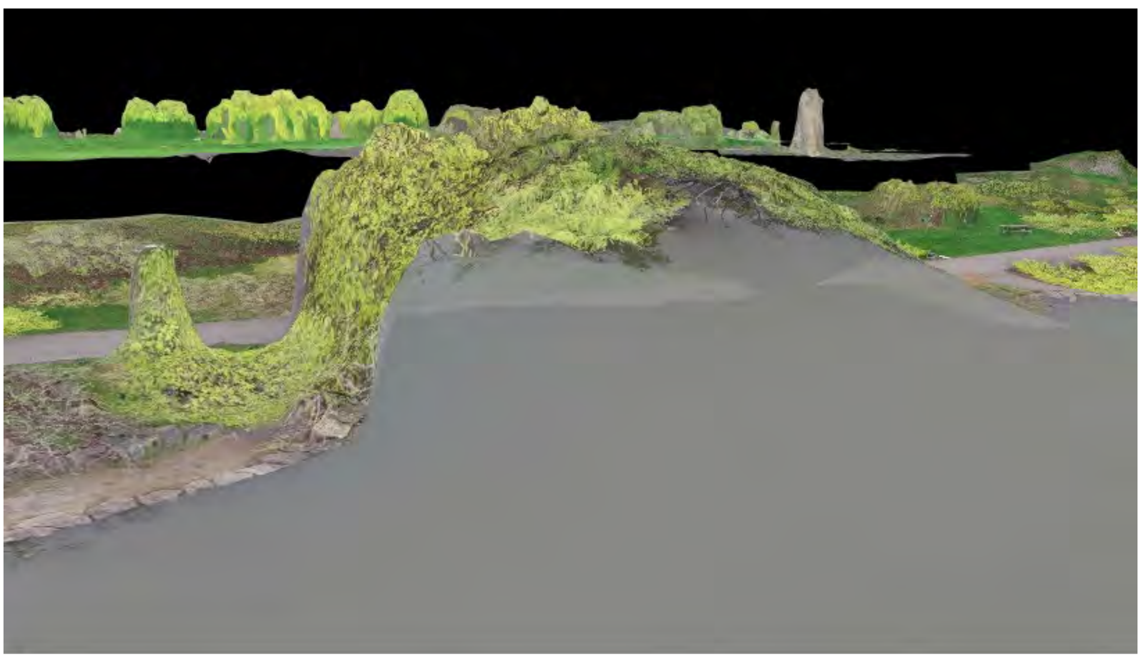


Figure 15 Example of UAV data with poor visibility due to vegetation growth and shading

- Wave model results – see Section 3.3.
- Wave effects based on wave model results and topo-bathymetry.
- Concepts for potential solutions

4.1 Assessment Rating System

The condition rating system used in this assessment is shown in Table 10. This rating system follows the standard created by SNC-Lavalin for shoreline assessment of port and coastal structure systems.

Sites that were recently protected with designs prepared by a registered Professional Engineer were not evaluated in detail and only high-level comments on the proposed or implemented solutions are included in this report.

The results of the condition assessment are described in Appendix C, and presented in a geo-referenced map in Appendix D.

The assessment findings and recommendations are based on the existing condition of the structure: it is not intended as a check of the original design.

Table 11 – Shoreline Protection Condition Rating System

Grade	Assessment
Very Good	Little to no wear visible. Reliability is of minor to no concern.
Good	Minor deterioration or defects are evident. Reliability is a minor concern.
Fair	Moderate deterioration in one or more portions of the asset. Reliability is a moderate concern.
Poor	Moderate to high levels of deterioration in portions of the asset. Reliability is a concern.
Very Poor	Higher levels of deterioration. Reliability is a serious concern.

4.2 Shoreline Assessment

The shoreline assessment is based on the visible current conditions of the City's properties. Whenever possible, SNCL commented on the impact of the adjacent properties.

A site by site summary of the assessed conditions and photo inventory is provided in Appendix C. An overview location plan showing the assessed sites is shown in Figure 16.

Elevations reported in this assessment refer to International Great Lakes Datum 1985 (IGLD), Chart Datum is 74.2 m IGLD.

Table 12 presents a summary of the conditions described in Appendix C per site and the respective average crest elevation of the shoreline / structure edge. It is important to note that the crest elevation is not the only parameter to define the site conditions; the character of the existing shoreline protection structure (or the absent of protection) and exposure to wind waves also contribute to the conditions.

Some of the sites indicated “good current conditions” but after reviewing bathymetry, topography, and wave climate, it was noted that the protection could be at risk during an extreme event. These sites are still rated as “good condition”, so it is important to interpret the rating with this qualification in mind.

Figure 16: Overview of Assessed Sites

Table 12 Summary of Assessment

Site Number	Site Name	Current Conditions	Crest Elevation (m IGLD)
1	Windermere Rd	Poor	76.8
2	Fifty Rd Parkette	Not Rated	-
3	Lake Vista Park	Very Good	77.2 / 78.8
4	Wendakee Dr	Fair	77.9
5	Winona Rd	Poor / Good	76.6
6	Private Road - Excluded	-	-
7	1137/35 North Services Rd Trillium	Poor	81.1 / 75.9
8	Lewis Rd	Poor	81.1 / 75.9
9	12 & 14 Trillium Ave	Fair	79.4
10	McNeilly Rd	Poor	78.7
11	52 Seabreeze Cr	Poor / Fair	76.6
12	Seabreeze Cr (Easement)	Good	76.9
13	Glover Rd	Good / Poor	78.7
14	Aquamarine Dr/Watershore Dr	Good	77.2 (top)
15	Jones Rd	Not Rated	78.3 - Design
16	Fruitland Rd	Fair / Very Poor	76.9
17	2 Frederick Ave, Frederick Parkette	Fair	78
18	33 Lakeview Drive (SWM)	Poor	76.6
19	497 & 503 Dewitt Rd	Good	77.5
20	Cherry Beach	Good	78.0
21	1st Private Rd - Excluded	-	-
22	Millen Rd Parkette	Poor	77.2
22B	Millen Rd Trail	Good / Fair	78.5
23	Frances Ave	Poor/ Good / Poor	77.4
24	Green Rd	Good	77.2
25	Lawrence P. Sayers Park (39 Lakegate Dr)	Good	77.2
26	655 Grays Rd	Good / Fair	76.9
27	Confederation Beach Park	See Table 13	Various
28	Hamilton Beach	Good	78.0 - 78.8
29	Hamilton Harbour Waterfront Trail	Not Rated	-
29B	Bayfront Park	See Table 13	Various
30	Macassa Bay Marina	Poor	75.9
31	Pier 4 Park	See Table 13	Various
32	Desjardins Canal	Not Rated	-
33	Woodland Cemetery	Not Rated	Various

Table 13 Sites 27 (see Appendix D for site number location)

Site Number	Current Conditions
27.1	Poor
27.2	Very Poor
27.3	Poor
27.4	Poor
27.5	Poor
27.6	Poor
27.7	Good
27.8	Good
27.9	Poor
27.10	Good
27.11	Poor
27.12	Fair
27.13	Fair
27.14	Fair
27.15	Poor

Table 14 Sites 29B (see Appendix D for site number location)

Site Number	Current Conditions
29.1	Poor
29.2	Poor
29.3	Very Poor
29.4	Fair
29.5	Poor
29.6	Fair
29.7	Very Poor
29.8	Fair
29.9	Poor
29.10	Fair
29.11	Fair
29.12	Poor
29.13	Good
29.14	Poor
29.15	Poor

Table 15 Sites 31 (see Appendix D for site number location)

Site Number	Current Conditions
31.1	Poor
31.2	Poor
31.3	Poor
31.4	Very Poor
31.5	Fair
31.6	Poor
31.7	Fair
31.8	Poor
31.9	Poor
31.10	Poor
31.11	Poor

5. Potential Design Solutions

The following sub-sections outline general design options which could be adapted for use at specific sites following a more site-specific detailed review.

5.1 Option A - Repair

This design option augments or ties into the existing shoreline protection, with the objective of mitigating existing damage in relatively localized areas (i.e. erosion limited to mid-slope or the crest). The repairs would not include changes to the crest height or location. As such, the repairs may not result in an overall solution that conforms to updated design criteria (recent water level data and storm events) or may not include adaptation for expected future climate change related effects. These repairs generally maintain the existing toe location and protection (if existing) and, typically, the existing slope.

Repairs could include the following measures, as illustrated in Figure 17 and Figure 18:

- Removal of armour or filter rock in localized areas to access and repair damaged geotextile.
- Removal of non-standard shoreline materials deemed non-suitable for reuse within the shoreline protection system.
- Placement of filter rock to match existing where the original ground or geotextile is exposed.
- Placement of armour rock to match existing slope protection or as-built drawings.

Figure 17 shows a generic Option A1 solution, where existing damage occurs on the rock slope. The repair consists of adding armour rock to match the existing design, and adds filter rock or geotextile where existing ground is exposed.

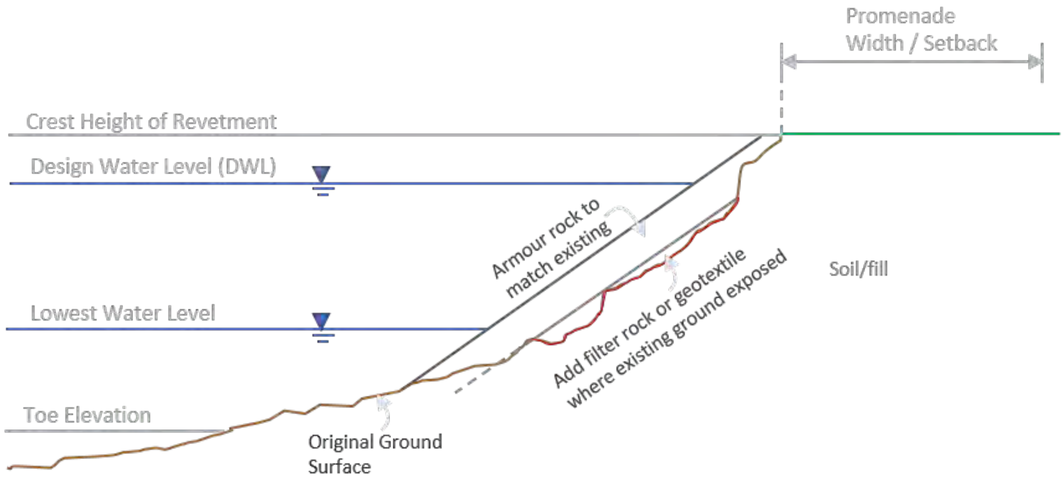


Figure 17 Option A1 Repair Solution

Figure 17 shows an Option A2 solution, where the damage occurs at the back of the crest and the existing structure consists of rock / concrete wall and armoured rock toe. The repair consists of adding appropriate filter rock where existing ground is exposed and complementing the area with vegetation. This is a frequent issue at the smaller sites where the crest is not at the required elevation.

The existing rock armour or wall might be designed and built to withstand the wave climate, but the back of the crest is not protected enough to receive and drain the overtopping volume during storm events without damage.

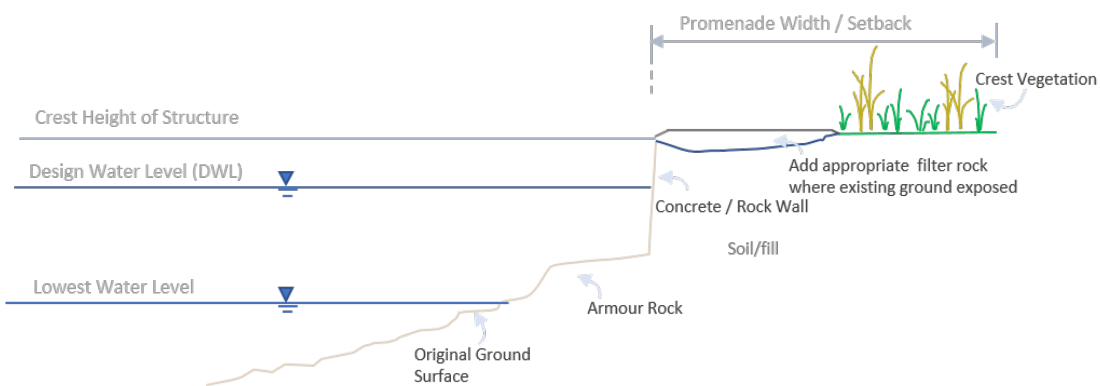


Figure 18 Option A2 Repair Solution

As the repairs do not include upgrades to the shoreline protection design – including slope, crest elevation, toe location, etc., the life of a repair will be contingent on the adequacy of the original design and construction of the slope protection for the wave climate and climate change. It is recommended that an evaluation regarding the structure conditions and stability to be undertaken after extreme events, and execute local repairs when necessary.

5.2 Option B – Replacement with Rock Armour Revetment

This design option replaces the existing shoreline protection with a new rock armour revetment design that meets updated design criteria (recent water level data and storm events). The new design could include a new crest height and location (if feasible), changes to the slope, toe location, and type/size of material.

This replacement design would likely include the following measures, as illustrated in Figure 19:

- Removal of existing shoreline protection, including rock armour, filter rock, and geotextile.
- Excavation and Fill as required to achieve the design grade.
- Placement of geotextile and filter rock.
- Placement of two-layers of armour rock to the new crest elevation.
- Restoration of upland area.

This option would cost more than the repair option, but have a higher resilience than a repair. The rock armour system will be suitable to be modified with a raised crest at a future date.

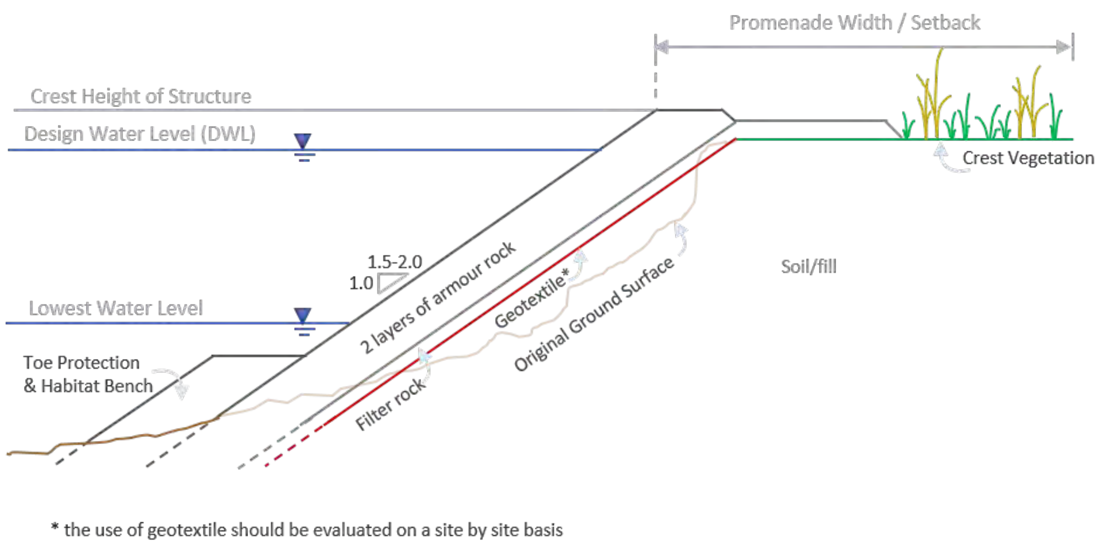


Figure 19 Option B Replacement Solution

5.3 Option C – Replacement with Rock Armour Revetment and Headwall

This design option replaces the existing shoreline protection with a new rock armour revetment and concrete headwall design that meets current design standards. The new design increases the crest elevation, and also likely changes the location of the crest, in order to increase resilience to wave overtopping and climate change. The design could also include changes to the slope, toe location, and type/size of material.

This replacement design would likely include the following measures, as illustrated in Figure 20:

- Removal of existing shoreline protection, including rock armour, filter rock, and geotextile.
- Excavation to the design grade.
- Construction of the headwall.
- Placement of geotextile and filter rock.
- Placement of two-layers of armour rock to the top of the headwall.
- Restoration of remaining upland area (if any).

This option would cost more than either Option A or B, but should have a greater lifespan and be more resilient to overtopping and climate change.

The headwall and crest of the new revetment should be designed considering the site location and the exposure to waves. In some cases, protection of the land behind the seawall might be necessary.

This solution can decrease the overtopping impact by raising the crest elevation with rock armour and headwall, avoiding the need to raise the upland site to an elevation sufficient to prevent flooding. This solution has the disadvantage of possibly obstructing the lake view and of hardening the shoreline.

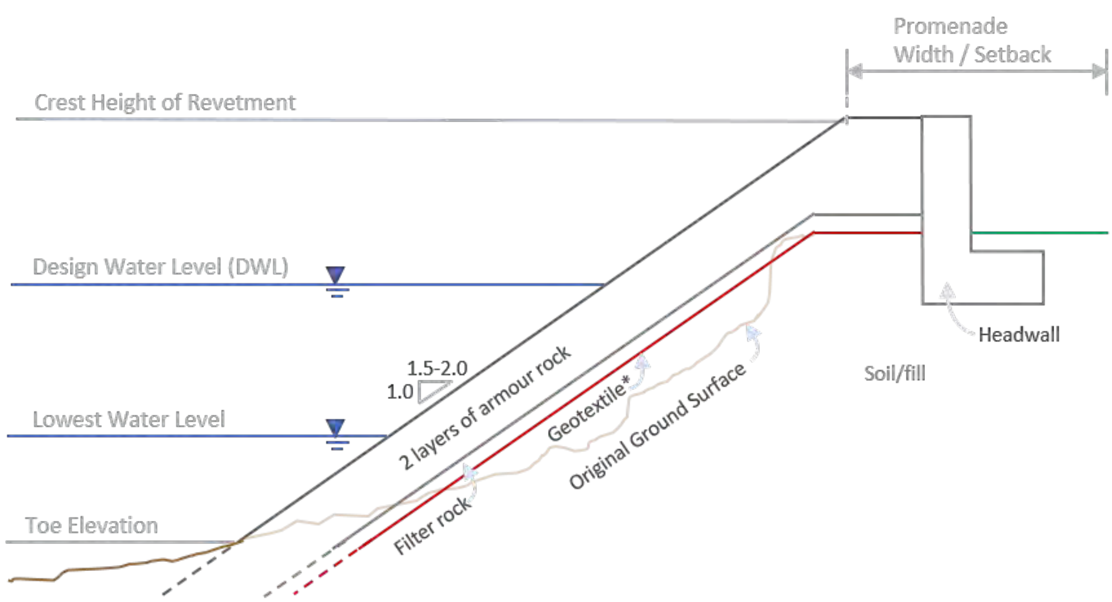


Figure 20 Option C Replacement Solution

5.4 Option D – Replacement with Submerged Habitat Reef and Gravel Beach

This design option is recommended where the City wants to avoid hard shoreline protection. This gravel beach should be considered on existing beach areas subject to shoreline erosion.

In general, the option consists of the addition of gravel fill on the beach area and creation of control points (headlands) or submerged habitat reefs to assist in stabilization of the gravel fill against alongshore transport. The gravel fill is designed to withstand or move locally (dynamic stability) according to the wave climate and sediment transport pattern of the site. The control points or submerged habitat reef will reduce the overall mobility of the new beach material.

The gravel beach may increase the crest elevation, and also the location of the crest, in order to increase resilience to wave overtopping and climate change; however, in many situations, the porous nature of the gravel may allow preservation of an existing shoreline crest elevation. The design could also include changes to the slope, toe location, and type/size of material.

This new design would likely include the following measures, as illustrated in Figure 21:

- Placement of new beach material such as gravel, pebble or cobble in mild slope.
- Installation of a shore parallel submerged or emergent rock reef on the low water profile.
- Placement or extension of existing headlands.
- Removal of existing shoreline protection, including rock armour, filter rock, and geotextile.

This option may cost less than Options B and C; however, it requires more design effort, including potentially, numerical and physical modelling.

The submerged habitat reef can also be replaced by the creation of a pocket gravel beach. The feasibility of this replacement must consider incident wave direction and sediment transport analysis on a site to site basis.

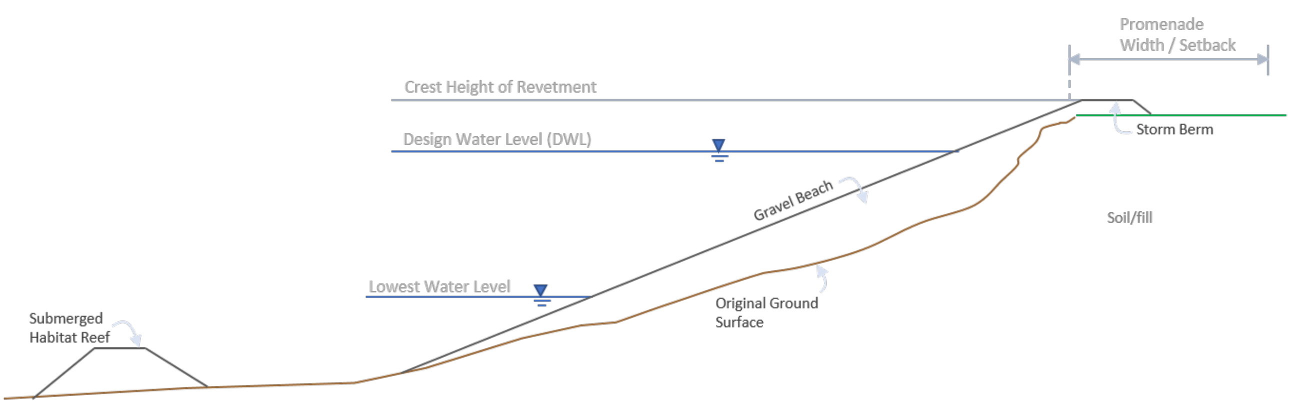


Figure 21 Option D Habitat Reef and Gravel Beach

5.5 Habitat Improvements

This section describes potential habitat improvements that could be incorporated into the design options presented above.

These habitat improvements could provide physical resilience services which depend on both natural processes and human activities to protect the urban shoreline. This resilience is related to the underlying preservation or enhancement of habitat and species biodiversity but also managing stormwater, wave interaction and surface water functions.

5.5.1 Habitat Bench

Design modifications, such as adding habitat benches to a revetment have previously increased habitat diversity (e.g., Ref. [4]). A bench could be added to the toe of the rock armour revetment in order to provide additional habitat and improve ecological functions. This bench would typically be located 1-2 m below average water level to provide maximum benefit. Figure 19 illustrates a habitat bench concept that would also provide toe protection for the rock armour revetment. Note that the bench can be either continuous along the entire shoreline, or can be built as discontinuous with variations in width to create a more natural undulating shoreline that (as a cost benefit) reduces the overall volume of materials.

Material size, shape, and texture could be adjusted to increase habitat diversity and promote usage from specific fish species and marine organisms. It may be possible that the existing shoreline protection material could be recycled and reused as the habitat bench.

5.5.2 Crest Vegetation

Vegetation could be added or preserved at the crest of the structure (as shown in Figure 19) to enhance both ecological and engineering services, such as the following:

- Enhancement of the riparian vegetation zone.
- Reduction of invasive species.
- Improvement of upland habitat supply and diversity.
- Enhanced resilience of the revetment to climate change, including wave overtopping and surface runoff.
- Reduced erosion of the crest and promenade.
- Improved safety for upland personnel, equipment, and infrastructure.

Trees should be preserved during construction in order to help provide a vegetated buffer, manage storm water and surface water functions, provide habitat, and manage heat island effects. However, preservation of trees often requires a larger working area setback to accommodate their growth. The roots of large trees may penetrate filter layers and geotextile liners or filter cloth and may affect the stability of the top of slope by the sheer weight of the tree alone. The presence of large trees or of associated root systems should be specifically assessed. Maintenance of the crest vegetation, particularly removal of invasive species, is required to control growth of invasive species while native plants are re-established. Once established, native plants would likely require less maintenance. Specific design and maintenance guidelines are necessary to be developed during the design phase.

5.5.3 Material Improvements

Recent research indicates that material improvements can be made in order to modify shoreline armouring to enhance habitat diversity, including making subtle changes to material shape, size, and texture.

Concrete blocks with a coarse surface were found to be more rapidly colonized by small green algae than those with a smoother surface (Ref.[5]). Geometric structures within the slabs (e.g., cups and holes) retain water longer during periods of low water and favour the initial colonization of larger green algae. Small adaptations of both the texture and structure of materials led to better settlement, colonization, and increased diversity of algae and macro benthos. Ultimately the creation of macro or micro habitats at a site can act to enhance foreshore habitat diversity and ultimately maintain ecological services.

Improvements of this sort could be made only with careful consideration of the engineering performance of materials.

5.6 Shoreline Solutions per Site

Table 16 summarizes the solutions and options recommended for each site based on this assessment.

More than one option is presented for some of the sites. The selection of the preferred option in these cases should be defined by the City's land use and available budget.

As shown in Table 12, a few sites (generally large sites) have more than one rating condition. In these cases, different solutions for the overall (large) site are identified that are particular to the conditions of each part of the site.

All sites rated in good conditions have a repair recommended (options A1 and A2), with the exception of Site 12 and Site 19, where even though the current structures presents good current conditions, they are likely not robust enough to withstand the expected wave effects during a severe storm event.

An improvement (remove concrete wall) was recommended for Site 3 Lake Vista Park, which was rated in very good condition.

Sites 29 and 31 are public use areas with part of the shoreline having low elevations when compared to recent high water levels. A Master Planning process is recommended where raising or rearranging pathways could be considered. Sections with elevations lower than high water levels will likely be flooded even if the shoreline is repaired.

Site 27 and 28 are beach areas with long stretches of natural shoreline. A Master Planning process is recommended to integrate the natural shoreline currently in "good condition" with solutions to the eroded sections of shoreline. As described in Appendix C, the solution for these sites includes different options of structures and mostly gravel beach solutions with supplementary protection from headlands or submerged habitat reefs.

Appendix C presents details and limitations for each site solution.

Table 16 Summary of Potential Solutions

Site Number	Site Name	Solution	Options
1	Windermere Rd	Replacement	B
2	Fifty Rd Parkette	-	-
3	Lake Vista Park	-	Improvement
4	Wendakree Dr	Repair	A2
5	Winona Rd	Replacement / Repair	B, C / A2
6	Private Road - Excluded	-	-
7	1137/35 North Services Rd Trillium	Replacement	D
8	Lewis Rd	Replacement	D
9	12 & 14 Trillium Ave	Repair	A2
10	McNeilly Rd	Replacement	B, C
11	52 Seabreeze Cr	Replacement	B / A1
12	Seabreeze Cr (Easement)	Replacement	B, C
13	Glover Rd	Repair	A1, A2
14	Aquamarine Dr/Watershore Dr	Repair	A1, A2
15	Jones Rd	-	-
16	Fruitland Rd	Repair / Replacement	A2 / B, C
17	2 Frederick Ave, Frederick Parkette	Repair or Replacement	A2, B, C
18	33 Lakeview Drive (SWM)	Replacement	D
19	497 & 503 Dewitt Rd	Replacement	B
20	Cherry Beach	Repair	A1, A2
21	1st Private Rd - Excluded	-	-
22	Millen Rd Parkette	Replacement	A1, A2
22B	Millen Rd Trail	Repair	A1, A2 / D (woodlot)
23	Frances Ave	Replacement / Repair	B, C / A1 / B
24	Green Rd	Repair	A2
25	Lawrence P. Sayers Park (39 Lakegate Dr)	Improvement	D
26	655 Grays Rd	Repair	A1, A2 (crest)
27	Confederation Beach Park	Repair / Replacement	See Table 17
28	Hamilton Beach	Repair / Improvement	A2 / D
29	Hamilton Harbour Waterfront Trail	-	-
29B	Bayfront Park	Repair / Replacement	See Table 18
30	Macassa Bay Marina	Replacement	C
31	Pier 4 Park	Repair / Replacement	See Table 19
32	Desjardins Canal	-	-
33	Woodland Cemetery	Replacement	D

Table 17 Potential Solutions site 27

Section Number	Solutions	Options
27.1	Replacement	D
27.2	Replacement	D
27.3	Replacement	D
27.4	Replacement	D
27.5	Replacement / Repair	A1 / B, D
27.6	Replacement / Repair	A1 / D
27.7	Replacement / Repair	A1 / D
27.8	Replacement / Repair	A1 / D
27.9	Replacement / Repair	A1 / B, D
27.10	Replacement / Repair	A1, A2 / D
27.11	Replacement / Repair	A1, A2 / B, D
27.12	Replacement / Repair	A1 / D
27.13	Replacement / Repair	A1, D
27.14	Replacement / Repair	A1, A2 / D
27.15	Replacement / Repair	A1 / B, D

Table 18 Potential Solutions site 29B

Section Number	Solutions	Options
29.1	Replacement	C
29.2	Replacement	C
29.3	Replacement	D
29.4	Repair / Improvement	A1, A2 / D
29.5	Repair / Replacement	A1, A2 / D
29.6	Repair / Replacement	A2 / B, D
29.7	Replacement	B
29.8	Replacement	A1, A2
29.9	Replacement	B, C
29.10	Improvement	D
29.11	Repair / Replacement	A1, A2 / D
29.12	Replacement	B, C, D
29.13	Replacement	B, C, D
29.14	Replacement	B, C, D
29.15	Replacement	B, C, D

Table 19 Potential Solutions site 31

Section Number	Solutions	Options
31.1	Repair / Replacement	A1 / B, C
31.2	Repair / Replacement	A1 / B, C
31.3	Replacement	B, C
31.4	Replacement	B, C, D
31.5	Repair	A1, A2
31.6	Repair / Replacement	A2 / B, C, D
31.7	Repair / Replacement	A2 / B, C, D
31.8	Replacement	C, D
31.9	Replacement	C, D
31.10	Replacement	B, C, D
31.11	Replacement	B, C, D

6. Conclusions and Recommendations

An in-depth review of the City's existing shorelines and current protection measures was undertaken by the Coastal Engineering team of SNC-Lavalin.

The Lake Ontario water level rise and the co-incident wind/wave storms are the main cause of the observed shoreline damage and erosion. Some of the existing shoreline protection solutions, including near vertical walls and impermeable structures are also increasing the wave effects, resulting in damage and ongoing erosion.

A summary of the current site assessments is presented in Table 20. Each site condition was rated following the standard system created by SNC-Lavalin for shoreline assessments described in Section 4.1. Sites that were recently protected by designs developed by a registered Professional Engineer were not rated. The evaluation is based on the current conditions of the shoreline (May 2019) and recommendations consider protection against effects of extreme events including the present high lake levels. Potential design solutions were associated with each site.

In general, the sites are exposed to low to moderate volumes of overtopping during severe storms at high lake levels. This exposure is due to the elevation (topography) of the shoreline and/or existing structure characteristics that increase the wave effects. In most cases a solution for small sites depends on the adjacent properties shoreline protections and performance. Preliminary options are given to larger sites (27 to 31), although they cannot have a single solution and it is recommended to initialize a Master Planning process to coordinate and prioritize the areas in need of rehabilitation

Raising or re-arranging pathways might be the most permanent solution for some areas of the large sites with existing low elevations and potential for flooding.

Recommendations and suggestions for repairs and replacement are given, although a permanent solution for many areas needs to be studied in more detail, giving consideration to City land use objectives.

Monitoring of all sites during high water level periods and storm events is recommended.

The potential solution options are summarized below.

A) Repair: augments or ties into the existing shoreline protection to mitigate damage in relatively localized areas. Two repair solutions are suggested:

A.1) Repair armoured slope

A.2) Repair crest and back of the crest

B) Replacement with rock armour revetment: replaces the existing shoreline protection with a new rock armour revetment design that meets current design standards

C) Replacement with rock armour revetment and headwall: replaces the existing shoreline protection with a new rock armour revetment and concrete headwall design that meets current design standards.

D) <u>Replacement with submerged habitat reef and gravel beach</u>: addition of gravel fill at the beach area and creation of control points (headlands) or submerged habitat reefs.

Habitat improvement can be created with any of the options above. Addition of habitat bench, crest vegetation and change in material are some of the improvements suggested for the sites.

The repairs suggested are provisional solutions to avoid further damage on the shoreline and should be detailed and carried out by experienced coastal engineers.

Table 20 Summary of Assessment and Solutions

Site Number	Site Name	Current Conditions	Solution	Crest Elevation (m IGLD)
1	Windermere Rd	Poor	Replacement	76.8
2	Fifty Rd Parkette	Not Rated	-	-
3	Lake Vista Park	Very Good	-	77.2 / 78.8
4	Wendakee Dr	Fair	Repair	77.9
5	Winona Rd	Poor / Good	Replacement / Repair	76.6
6	Private Road - Excluded	-	-	-
7	1137/35 North Services Rd Trillium	Poor	Replacement	81.1 / 75.9
8	Lewis Rd	Poor	Replacement	81.1 / 75.9
9	12 & 14 Trillium Ave	Fair	Repair	79.4
10	McNeilly Rd	Poor	Replacement	78.7
11	52 Seabreeze Cr	Poor / Fair	Replacement	76.6
12	Seabreeze Cr (Easement)	Good	Replacement	76.9
13	Glover Rd	Good / Poor	Repair	78.7
14	Aquamarine Dr/Watershore Dr	Good	Repair	77.2 (top)
15	Jones Rd	Not Rated	-	78.3 - design
16	Fruitland Rd	Fair / Very Poor	Repair / Replacement	76.9
17	2 Frederick Ave, Frederick Parkette	Fair	Repair or Replacement	78.0
18	33 Lakeview Drive (SWM)	Poor	Replacement	76.6
19	497 & 503 Dewitt Rd	Good	Replacement	77.5
20	Cherry Beach	Good	Repair	78.0
21	1st Private Rd - Excluded	-	-	-
22	Millen Rd Parkette	Poor	Replacement	77.2
22B	Green Millen Waterfront Trail	Good / Fair	Repair	78.5
23	Frances Ave	Poor/ Good / Poor	Replacement / Repair	77.4
24	Green Rd	Good	Repair	77.2
25	Lawrence P. Sayers Park (39 Lakegate)	Good	Improvement	77.2
26	655 Grays Rd	Good / Fair	Repair	76.9
27	Confederation Beach Park	Various	Repair / Replacement	Various
28	Hamilton Beach	Good	Repair / Improvement	78.0 - 78.8
29	Hamilton Harbour Waterfront Trail	Not Rated	-	-
29B	Bayfront Park	Various	Repair / Replacement	Various
30	Macassa Bay Marina	Poor	Replacement	75.9
31	Pier 4 Park	Various	Repair / Replacement	-
32	Desjardins Canal	Not Rated	-	Various
33	Woodland Cemetery	Not Rated	Replacement	76.8

Table 21 Site 27 Assessment and Solutions

Site Number	Current Conditions	Solutions
27.1	Poor	Replacement
27.2	Very Poor	Replacement
27.3	Poor	Replacement
27.4	Poor	Replacement
27.5	Poor	Replacement / Repair
27.6	Poor	Replacement / Repair
27.7	Good	Replacement / Repair
27.8	Good	Replacement / Repair
27.9	Poor	Replacement / Repair
27.10	Good	Replacement / Repair
27.11	Poor	Replacement / Repair
27.12	Fair	Replacement / Repair
27.13	Fair	Replacement / Repair
27.14	Fair	Replacement / Repair
27.15	Poor	Replacement / Repair

Table 22 Site 29B Assessment and Solutions

Site Number	Current Conditions	Solutions*
29.1	Poor	Replacement
29.2	Poor	Replacement
29.3	Very Poor	Replacement
29.4	Fair	Repair / Improvement
29.5	Poor	Repair / Replacement
29.6	Fair	Repair / Replacement
29.7	Very Poor	Replacement
29.8	Fair	Replacement
29.9	Poor	Replacement
29.10	Fair	Improvement
29.11	Fair	Repair / Replacement
29.12	Poor	Replacement*
29.13	Good	Replacement*
29.14	Poor	Replacement*
29.15	Poor	Replacement*

Table 23 Site 31 Assessment and Solutions

Site Number	Current Conditions	Solutions
31.1	Poor	Repair / Replacement
31.2	Poor	Repair / Replacement
31.3	Poor	Replacement
31.4	Very Poor	Replacement
31.5	Fair	Repair
31.6	Poor	Repair / Replacement
31.7	Fair	Repair / Replacement
31.8	Poor	Replacement
31.9	Poor	Replacement
31.10	Poor	Replacement
31.11	Poor	Replacement

7. References

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8. Revision Index and Signatures

Issue Code	Rev. No	Date (yyyy-mm-dd)	Description of Changes	Initials
RR	PA	2019-08-21	Issued for Internal Review	GMJ
RR	PB	2019-08-23	Issued for Review and Comments – Preliminary Draft	GMJ
RR	PC	2019-09-25	Issued for Review and Comments –Draft	GMJ
RR	PD	2019-10-17	Issued for Review and Comments –Draft with Appendices	GMJ
RI	R0	2019-11-06	Final Report	GMJ

Issue Codes:

RC Released for Construction
RD Released for Design
RF Released for Fabrication
RI Released for Information
RP Released for Purchase
RQ Released for Quotation
RR Released for Review and Comments

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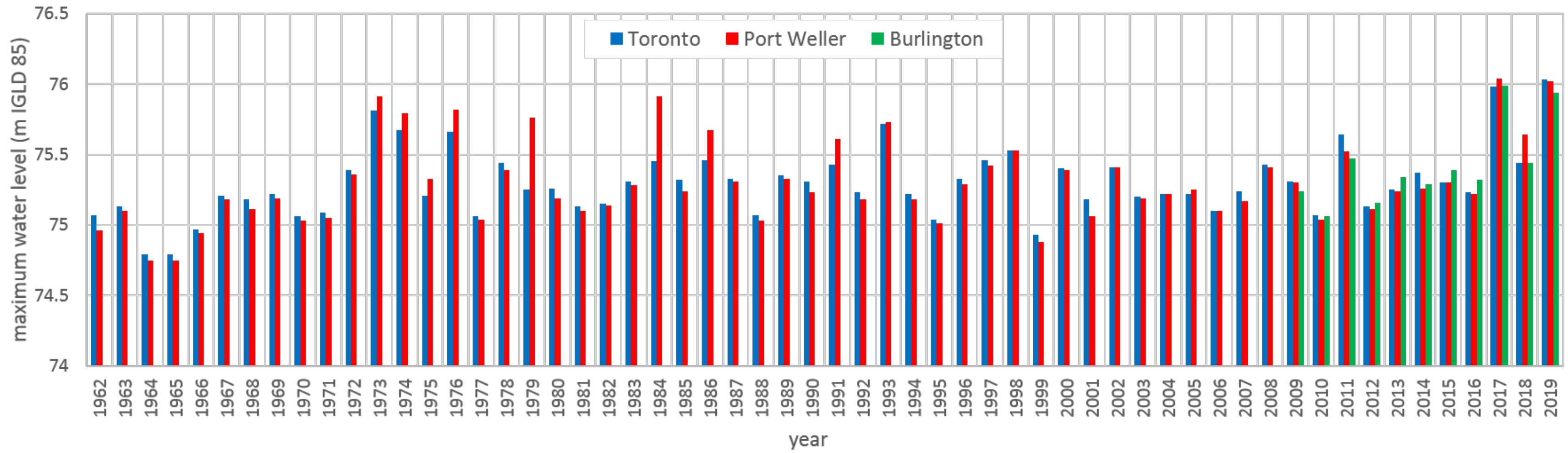
Appendix A

Yearly Minimum and Maxima Water Level (1962-2019)



Toronto
Port Weller
Burlington
maximum water level (m IGLD 85)
76.5
76
75.5
75
74.5
74
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
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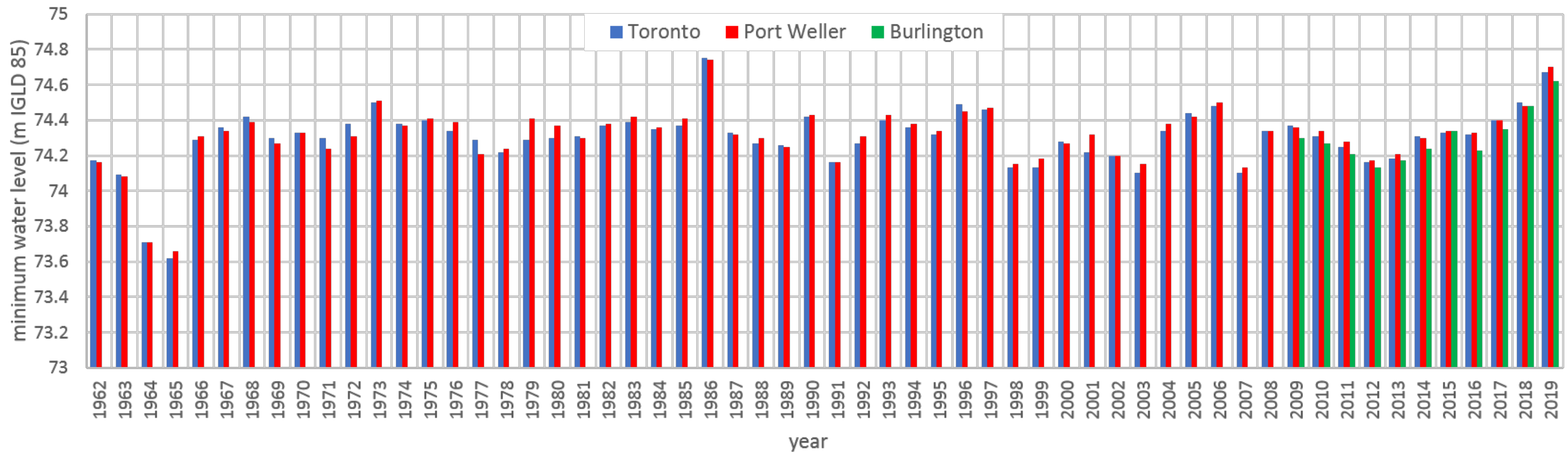
2019
year



Toronto
Port Weller
Burlington
minimum water level (m IGLD 85)
year

Appendix B

Field Investigations

Field Investigations

City of Hamilton

Final Report

21 | 08 | 2019

1 Approach and Methodology

1.1 Context

SNC-Lavalin was hired by the City of Hamilton to assess the condition of their shoreline properties. A topographic and bathymetry survey as well as Digital Elevation Model (DEM) imagery were used to create a record of current site conditions, provide information for a coastal engineering analysis and facilitate the generation of shoreline protection solutions.

Remote sensing is a commonly-used tool for planners. It allows planners to conduct a desktop analysis of the site while achieving a comparable precision to a regular field survey. While traditional remote sensing imagery is two-dimensional, the addition of elevation data and imagery in a DEM can be used to visualize the site, which then eases the later stages of the project.

A DEM is a 3D representation of a terrain's surface. It can be used for watershed modeling, civil engineering, wireless communications purposes, cartography/base mapping and is commonly used in the mining industry for planning, risk management and improvements to safety. 'Traditional' satellite images on the other hand, do not have an altitudinal component, forcing the user to imagine the elevation.

Satellite imagery is an efficient and reliable tool for planners however, its limitations lie in the fact that the user cannot control the time, quality, or the ground cover of the image. This may result in a delay to the project as the user will need to wait for an appropriate image to be taken at the desired time and location. And even then, the image could be partially (or fully) covered by clouds. Additionally, elevation data cannot be extracted through satellite imagery.

A common solution to these constraints is to use a drone. Drones fly at a low altitude, below the cloud ceiling, and are more likely to capture images that are completely free of obstructions. Further, the drone's path can be entirely programmed, so only the desired area is captured. Extra benefits are listed below:

- Creates high-resolution cartographic outputs whish are precise and rapidly acquired
- Alleviates field time considerably
- Rapid delineation of natural habitats
- Can be used for site monitoring over time
- Water levels can be monitored using 3D modelling;
- Ability to access remote sites and locations that are difficult to navigate on foot

The images captured from the drone can be used to clearly and accurately communicate information to stakeholders. The images can also be used by the firm itself for planning and developmental purposes. DEM imagery can also benefit subcontractors as it not only reduces the number of site visits, but also allows for more flexibility for the timing of those visits.

2 Methodology

2.1 Reference System

2.1.1 Horizontal Datum

Geographical positions are reported in UTM zone 17 North coordinates. Positions will be referenced to the NAD83 datum. The coordinate system will be identified with the project's metadata.

2.1.2 Vertical Datum

All depths are reduced to a low water datum. In non-tidal waters, the depths are reduced to the chart datum (IGLD85).

2.1.3 Positioning

Real Time Kinematic (RTK) GPS positioning techniques are employed on all bathymetric surveys.

Positioning of field measurements is done using an RTK survey grade GPS system (Trimble R8 rover with VRS corrections) with centimeter precision. Recording of GPS raw data is done since it provides backup data and provide for increase accuracy when post processed.

2.2 Drone Survey

The drone model used by SNC Lavalin is a Phantom 4 Pro V2 from DJI (specifications are Figure 1) and is a small pilotless quadcopter that is less than one square meter in size and approximately 1375 grams in weight. It is radio-guided and follows a predefined flight plan using its built-in GPS. The drone flies between 2 and 72 km/h and can resist winds speeds of up to 35 km/h. Its Terrain Follow feature maintains a consistent height above uneven terrain. Additionally, it is equipped with a 20-megapixel camera, allowing high-resolution aerial photography.

Figure 1 Phantom 4 Pro specification sheet

Under optimal conditions, the drone can fly for approximately 30 minutes, or 14 km. A full battery can cover approximately 30 hectares in 22 minutes at an altitude of 75 m and a speed of 15 m/s, resulting in a ground resolution of 2 cm for the images, and 75% lateral and frontal cover for each image.

These parameters can be adjusted based on the client's needs. For example, the same flight above can be changed to an altitude of 100m with a ground resolution of 3 cm. The final georeferenced image has a ground resolution accuracy of 0.3 m for the x and y axes and 0.5m for the z-axis.

Our geometrician, Julie Camy, has a professional Drone Pilot's license (2017) from I drone Montréal. She is familiar with Canadian drone laws and has professional insurance for the device. She joined SNC Lavalin team in February of last year.

2.2.1 Preliminary Steps

A preliminary desktop study is conducted to confirm that the area is compliant with Transport Canada Air Regulations. In our study area we have 2 hospitals with heliports, so a flight authorization is needed for some areas (Figure 2) We also asked for a flight authorization for the City of Hamilton (Figure 3).

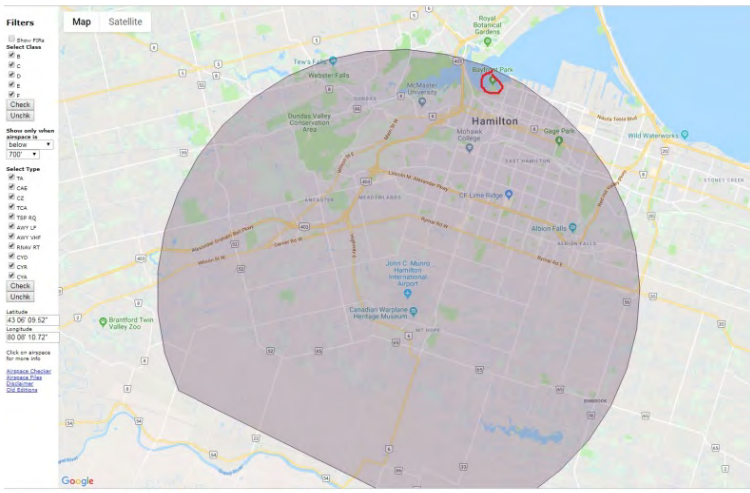


Figure 2 Example of airport constraints

Prior to flying, some preliminary steps are completed to prepare the drone for flying. They are listed as follows.

<u>Field Preparation</u>

- For safety reasons, a site survey is conducted to identify any obstructions or barriers that could harm or complicate the flight plan (tall structures, tower plant etc.), and a final decision is made on the location for takeoff and landing.
- An estimate of the zone to be covered will be made in order to plan for the appropriate amount of materials (batteries, etc) and to ensure a smooth field experience.
- 35 flight sites were identified to in our study area:
  - From zone 1 to 26 all along the shore line
  - Zone 27 A, B, C and D are all along the main beach
  - Zone Desjardins Bridge, Woodland Cemetery, Bayfront Park, Macassa Bay, and Bay Front Pier are located inside the bay.

<u>Field work and Flying</u>

- An appropriate meteorological window is chosen a few days before the flight.
- The drone pilot or the surveyor uses the Trimble R10 GNSS system to mark the GCP's (Ground Control Points) in the appropriate location to ensure an accurate measurement.
- In the field, the pilot stands in one place and sends the drone out on these pre-determined paths. This simple procedure is repeated until the desired surface area is covered.
- All the sites were flown over twice. Once with an automatic flight plan for imagery acquisition for creating Mosaic 2D images and cloud point processing, then another manual flight was done for Oblique picture acquisition.

Figure 3 Example of flight plan

2.2.2 Data Acquisition and Processing

2.2.2.1 Data Acquisition

The drone survey was conducted within 3 days from May 14th – May 16th. Prior to each flight the drone pilot completed a visual inspection to ensure the area is clear for flying. An orange cross (GCP) was marked on the ground in an area where the bathymetry survey was conducted. The exact location of the GCP will be taken with Trimble R10 GNSS in order to calibrate the system. The drone is then launch for a first autonomous flight on the area acquiring a lot of images to create a detailed 2D picture. Then the drone is launched a second time for oblique picture acquisition.

It should be noted that zone 27 A, B, C, and D are flown at a higher altitude because of the vicinity of power line along the beach.

2.2.2.2 Data and Image Processing

Once the survey is completed, the images are processed using DroneDeploy software. At this stage, the images are georeferenced, orthorectified, and collated respectively to create an orthomosaic photograph. The drone's aerial view provides information on the altitude of the objects in the image, which is the basis for the creation of a base numerical elevation map. The resulting models can be used to create maps for reference, visualize topography for runoff calculations, calculate the elevation of surfaces, and/or find the volumes of different features. Image treatment times vary depending on the number of images taken in the field and the image complexity. Commonly, 8-24 hours of image processing are expected for each full field day. Note that this is a largely hands-off process. GCP's, which are accurate to less than 10cm, are then added to the map to increase the resolution and accuracy of the models. A digital map and orthophoto can then be produced. Using point clouds, a rich textured 3D model is generated to create an industrial standard DEM, orthophoto and contour/topographical maps.

Photogrammetry techniques include the process of registering, quantifying and analyzing recorded images and patterns to obtain precise measurements of physical object. Aerial land mapping and surveying using photogrammetry significantly eases the job of analyzing land for site selection, structure planning and progress monitoring of civil or mine projects. It reduces data acquisition time from months to days. The output can be used as a base map for GIS applications, digital elevation models, contour maps, volumetric analysis etc. Unmanned Aerial Vehicle (UAV) based aerial photogrammetry is not only increasing close range remote sensing applications, it is also increasingly used as an alternative to manned aerial photogrammetry.

Figure 4 High density point cloud

2.2.3 Results and Deliverables

DroneDeploy allows for a handful of different file methods to view the data collected. Deliverables to be submitted to the City of Hamilton however, will include for each zone:

- 2D high resolution mosaic in Geotiff format and NAD 83 CSRS MTM-Zone 10 projection system
- The dense cloud point in XYZ format at NAD 83 CSRS MTM-Zone 10 projection system
- 3D model at obj format
- MXD map and LYR file to open all the mosaic with ArcGiS software.

After exporting the cloud points, we notice that there is some discrepancy in measurements between the drone and field data even after incorporating GCP's in the map. We suspect that while in flight, the accuracy of the drone's measurements was affected by the number of satellite GPS connections the drone had at that point in time. You can see in Figure 4 that the drone had some difficulties acquiring enough connections throughout the flight. A weak connection to satellites can result in 1-3 feet of error in the resulting data. This may explain the error we found after extracting and processing the data.

GPS Satellite Count Map - green is excellent GPS reception, orange is good, red is poor and purple is dangerous:

Download color coded GPS KML

For improved visibility of GPS satellite coverage, color is based on the lowest satellite count within the specified range:

	Flight time	Altitude	Home Distance	GPS Satellite Range	Lowest Satellite Count
A	00m 00s	0.0 ft	0 ft	10-16	10
B	01m 55s	71.5 ft	116 ft	15-18	15
C	06m 08s	65.6 ft	1,231 ft	14-16	14
D	06m 10s	65.6 ft	1,243 ft	15-18	15
E	08m 30s	65.0 ft	1,334 ft	13-18	13
F	08m 35s	65.9 ft	1,331 ft	15-18	15
G	12m 40s	12.5 ft	3 ft	12-16	12

Figure 5 Example of drone losing GPS satellite connection

The accuracy of the next drone survey can be improved by following these steps:

- Work with a Phantom 4 RTK and D-RTK2 mobile station to avoid GPS satellite connection problems.
- If the Phantom 4 Pro V2 is still being used, we can add more GCP's on the map to increase the number of reference points.
- Add checkpoints on each map to verify the accuracy of the map as GCP cannot provide the RMSE.

Although the accuracy of the point data is not completely accurate, the relative distance between each point is accurate. As a result, distance or slope measurements will be correct. The absolute elevation will only be degraded by the lack of GPS satellite connections.

2.2.4 Drone Survey Limitations

Although surveying with a drone can fast track data acquisition or improve visualization, it also has limitations. Some noteworthy ones are listed below:

- The drone cannot fly or will acquire faulty data while flying in adverse weather conditions such as strong winds (>45 km/h or 25 knots), heavy rain, or extreme cold conditions (less than -20°C)
- Proximity to power lines can create high compass interference within the drone.
- Dense vegetation coverage will produce an incomplete 3D model because the drone cannot acquire information under trees.
- Lack of GPS satellite connection of the drone will decrease the accuracy of the photogrammetry in the drone and result in difficulties maintaining consistent altitude and flight plan.

Figure 7 Trees covering line of sight

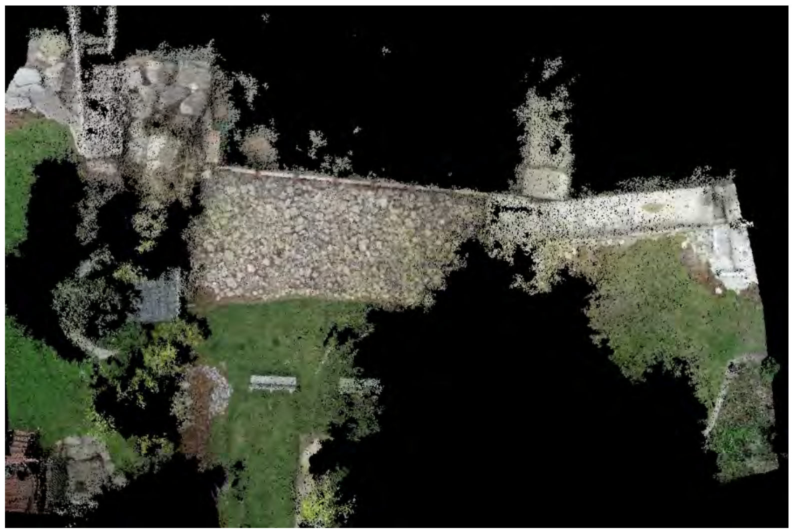


Figure 6 Model resulting from trees

2.3 Single Beam Bathymetry Survey

2.3.1 Data Collection

All SBES surveys are conducted using survey grade GPS (RTK, PPK). Synchronization of the soundings, positions and heading data was made directly through the GPS controller. All raw data (bathymetric data, was be recorded, integrated and synchronized in the controller.

Specific survey sites were defined according to specific needs determined by the wave modelling team.

2.3.2 Field QA/QC

System Integration and Referencing

The SBES bracket system (SBES + GPS) was measured before starting the survey. The calibration consists in calculating the offsets of all sensors with respect to the reference point. In this case, the echosounder is considered as the reference point. These offsets will be measured prior to the survey using a measuring tape. Static offsets will be measured in X, Y and Z.

Reference point (echosounder) to GPS antenna

The GPS antenna and the transducer will be installed on the same support on the side of the boat. The GPS antenna will be installed directly above the head of the transducer. The offsets between the GPS antenna and the face of the transducer will be measured prior the survey and included in the controller.

The SBES is given a trial run at the beginning of the survey to ensure that the sounder and the rest of the equipment perform according to their specifications.

Speed of survey

An acquisition methodology is established and takes into consideration the survey requirements. The survey speed for the boat and the ping rate of the SBES will be adjusted so that the appropriate density of soundings is measured along the survey line.

Survey lines

SBES survey is conducted while running lines perpendicular to the shoreline,

If processing of the sounding data is not possible during the duration of the survey, certain checks are completed before leaving the site to ensure the survey quality:

- All sensors have been adequately calibrated/verified;
- Review of survey coverage;
- Randomly select subsets of data while collecting to verify consistency and quality of data;
- Collect water level data;
- Verify the overall data quality;

Data acquisition involves the proper collecting and recording of information. All written information is understandable to anyone who may want to look at it later. All physical records are properly filed and kept in a safe place. Backups of the data are made, and the storage device will be kept in a different location than the main computer.

2.3.2.1 Data processing

General information

SBES data will be processed using AutoCAD. Soundings are verified in AutoCAD to remove erroneous values (0, double echoes, false bottom and vegetation artefacts, etc.).

QA/QC During Data Processing

The details of the GPS installation including the reference system, datum, benchmark information, equipment models, horizontal azimuth, antenna height and any other helpful information will be entered on the field sheets.

Built in filters can be applied to eliminate erroneous data (bad GPS mode, large offset from planned line, etc.). The data will be analyzed, and any residual anomalies will be deleted.

The final data files with detailed metadata will be thoroughly checked for completeness and format before the report is submitted.

2.3.2.2 Deliverables

The following deliverables will be provided:

- Metadata
- CSV file including Northing, Easting and elevation data
- Project Report

Figure 3-5 Outfall protected by concrete walls

Figure 3-6 Overview wall with outfall

Site 4 Wendakee Drive – Assessed Condition: Fair

Site 4 is a street right of way (RoW) consisting of natural grass area with public access. The site shoreline, of approximately 25 m length, is protected by a vertical concrete wall and there is a guard rail in reasonable condition on the top of the wall. An outfall channel that discharges through the concrete wall is protected on the west side by large rocks and on the east side by the adjacent property shoreline protection (armour rock), Figure 4-2.

The transition between the concrete wall and the east adjacent property protection is by an old timber wall (approximately 1.5 m long), which was likely the previous protection of the site. The area landward the timber wall is a weak point on the shoreline and erosion was observed. Erosion was also observed on the shoreline close to the transition between the concrete wall and the west adjacent property whose shoreline protection consists of three layers of approximately 2 – 3 m long concrete blocks.

The elevation of the concrete wall is approximately 78 m and wave overtopping during storms likely reaches the backside of the wall. It is recommended to protect the upland area behind the wall to reduce damage due to overtopping and reduce surface run-off.

Drainage solutions could also be reviewed to decrease potential erosion, a drainage pipe is located close to the west end of the wall and could be contributing to the erosion around the area. A grassed drainage channel connects the property land to the pipe. Adding a rock protection blanket to the part of the channel close to the shoreline could also reduce erosion.

Site 4 Wendakee Drive	
Conditions	Fair
Crest Elevation	77.9 m IGLD
Solution	Repair
Options	A2

Site 4 Wendakee Drive – Photo Inventory

Figure 4-1 Site 4 Oblique view (middle section) and adjacent properties

Figure 4-2 Concrete wall, outfall channel and armour rock protection

Figure 4-3 Site 4 Overview

Figure 4-4 Timber log wall completing wall

Site 5 Winona Rd – Assessed Condition: Poor / Good

Site 5 is a street right of way (RoW) with an asphalt pathway to the shoreline and a storm outfall. The shoreline is protected by large rectangular rocks (approx. 1.5 m). The system consists of one rock layer with top elevation of approximately 76.7 m. The large rocks seem to be stable but significant erosion of the crest was observed at the asphalt pathway. The crest is composed by rocks not large enough to theoretically withstand the overtopping volume experienced. The crest is significantly eroded in the east part of the site with exposed (and deteriorated) geotextile, there is also loss of grass area. The crest is not stable, and it might be a safety concern for public safety.

On the east side of the property, the neighbours' shoreline protection is comprised by three layers (visible) of concrete blocks, there are gabions (close to failure) at the boundary with the City's property. The concrete blocks close to the boundary are not stable, likely being undermined by the back of the crest (landward) erosion. A few rocks angled have been backfilled with large riprap.

A large storm outfall channel, protected by large rocks under the concrete wall, is present at the west end of the site. The exit of outfall channel is in reasonable condition. It was noticed there is accumulation of small rocks at the channel entrance, likely transported during storms.

The current conditions of the shoreline are generally good at the west channel but fair on the east part of the site.

It is recommended that a transition from the large rock armour at the channel to the grass area is installed with smaller rocks to improve drainage and avoid erosion.

The east side of the site should be redesigned to include a sloped armour to reduce wave energy, the slope will likely encroach the lake or cut back the grass area with reinforcement of the crest and back of the crest. The gabion structures should also be replaced. The protection of this part shoreline is subject to the conditions and performance of the east adjacent property.

Site 5 Winona Rd		
Conditions	Poor	Good
Crest Elevation	76.6 m IGLD	
Solution	Replacement	Repair
Options	B, C	A2

Site 5 Winona Rd – Photo Inventory

Figure 5-1 Site 5 Oblique view

Figure 5-2 Site 5 eroded crest

Figure 5-3 Site 5 Winona Dr.

Figure 5-4 Site 5 Winona Dr.

Figure 13-5 Site 13 Glover Rd.

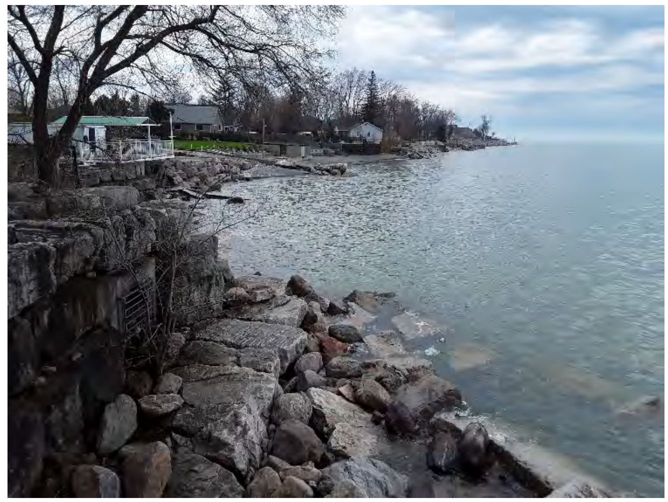


Figure 13-6 Site 13 Glover Rd.

Site 14 Aquamarine Dr / Watershore Dr – Assessed Condition: Good

Site 14 is characterized by a three-layer large rock armour protection system, which incorporates a concrete outfall channel in the middle of the site. The site was not accessible during the site visit due to the intense vegetation growth, so the assessment is based on the images and data collected by a drone over flight.

The structure surrounding the channel is 20 m long and is subject to a high volume of overtopping during extreme events at high water level periods. The crest elevation ranges from approximately 77.2 m (shoreline) to 78.8 m landwards.

The shoreline is in very good condition, but it is important to note that the concrete channel might get damaged during severe storm events at high lake levels due to the resulting wave forces on the shoreline protection system. It is recommended to monitor the structure and protect the channel with rocks at the first signs of damage.

It is noted that the gaps between the interlocked armour, laid side by side, are filled with smaller rocks. Monitoring of the gaps after extreme events is recommended with replacement of any dislodged fill if necessary.

The permeability of the rock structure is important to the performance of the structure when high volumes of overtopping is predicted.

Site 14 Aquamarine Dr/Watershore Dr	
Conditions	Good
Crest Elevation	77.2 (top) m IGLD
Solution	Repair
Options	A1, A2

Site 14 Aquamarine Dr / Watershore Dr – Photo Inventory

Figure 14-1 Site 14 oblique view

Figure 14-2 Site 14 Aquamarine Dr. / Watershore Dr.

Site 15 Jones Rd – Assessed Condition: Not Rated

The Site 15 shoreline protection system was under construction during the site visit for the condition assessment. This site is being constructed by a private developer on behalf of the City as part of a residential development (“Waves”). The engineered design includes two layers of armour rock (3-5 tonnes) from elevation 73 m to 77.5 m, followed by two cap armour stone (2-4 tonnes) at the crest, reaching 78.3 m and 225-450 mm rip rap on the back of the crest at a lower elevation (77.5 m).

The new structure will be exposed to low to moderate levels of overtopping and it is recommended to monitor the concrete headwall at the slope because of the expected wave forces during high water levels and severe storms. The back of the crest should also be reinforced, suggestion adding one or two cap armour stone and a transition to smaller rocks to avoid erosion and improve drainage.

Site 15 Jones Rd	
Conditions	Not Rated
Crest Elevation	78.3 (design) m IGLD
Solution	-
Options	-

Site 15 Jones Rd – Photo Inventory

Figure 15-1 Site 15 Jones Rd.

Figure 15-2 Site 15 Jones Rd.

Figure 15-3 Site 15 Jones Rd.


Figure 19-5 Site 19 497 and 503 Dewitt Rd.

Site 20 Cherry Beach – Assessed Condition: Good

Site 20 has a robust shoreline protection system completed in 2016. Based on the current site conditions and a preliminary review of the detailed design drawings, the following comments are provided:

- It is assumed that the aquatic habitat feature is not part of the shoreline protection system due to the limited structure height.
- Drainage should be taken into consideration and use of the geotextile should be re-examined.
- The area behind the crest is eroding, likely due to overtopping and associated drainage.
- Top of crest elevation is approximately 78.5 m (from design) and is exposed to low to moderate overtopping volumes.
- An excavated toe is present in the design drawings.
- The storm water channel needs repair.
- Part of the shoreline (private property) should be protected to avoid weak points that might start damaging the City shoreline.
- Filter criteria should be checked for the rock sizes between layers to improve drainage and avoid loss of material during extreme events.
- It is recommended to extend the back of the crest protection with attention to creating a smooth transition between rock sizes.

Site 20 Cherry Beach – Photo Inventory

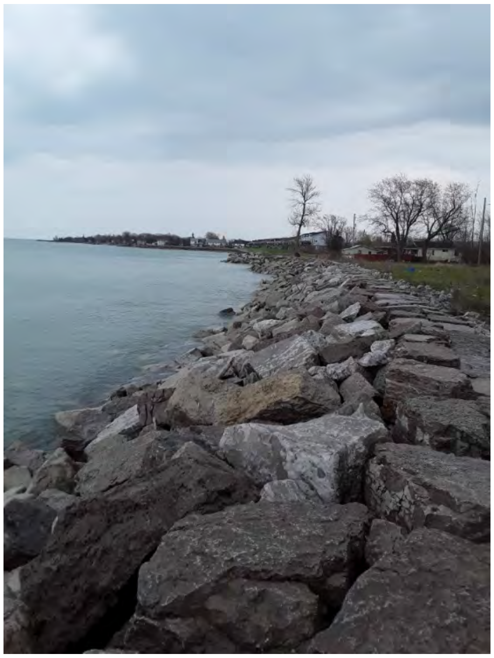


Figure 20-1 Overview of Rock Armour System

Figure 20-2 Erosion at the Back of Crest

Figure 20-3 Site 21 Cherry Beach

Figure 20-4 Site 21 Cherry Beach

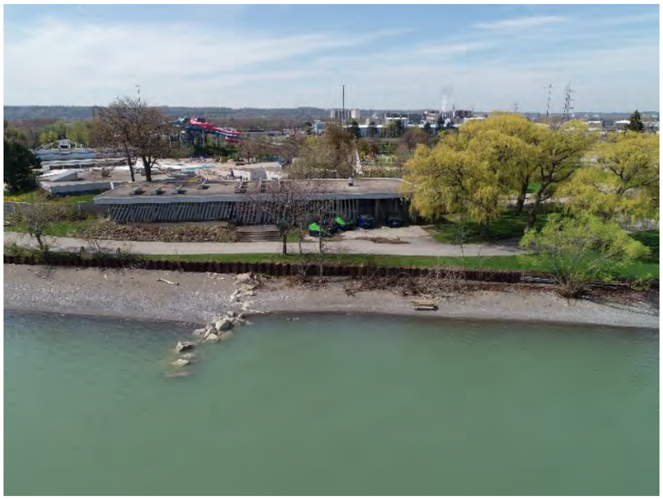


Figure 27-7 Site 27 Sheet Pile Wall


Figure 27-8 Site 27 Rock armour, debris and fallen trees


Figure 27-9 Site 27 Structure out of service

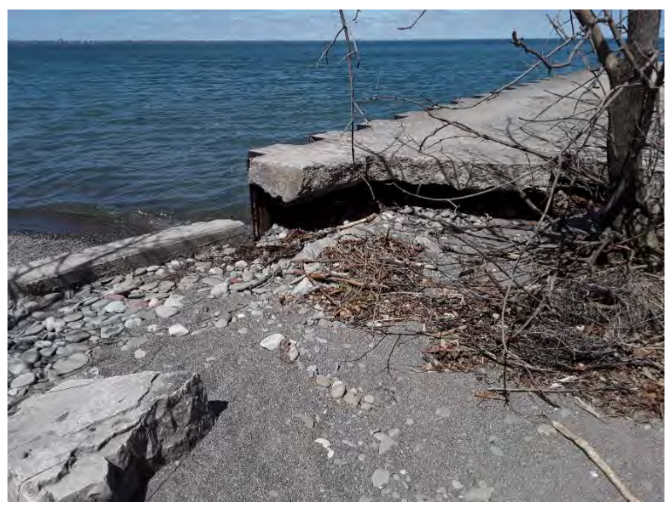


Figure 27-10 Site 27 Deterioration of structure

Figure 27-11 Site 27 Asphalt pathway erosion

Figure 27-12 Site 27 Sedimentation

Figure 27-13 Site 27 Unprotected shoreline subject to erosion

Figure 27-14 Site 27 Shoreline protection structure

Figure 27-30 Site 27.07 Confederation Beach Park

Figure 27-31 Site 27.07 Confederation Beach Park

Figure 27-32 Site 27.07 Confederation Beach Park

Figure 27-33 Site 27.08 Confederation Beach Park

Figure 27-34 Site 27.08 Confederation Beach Park

Figure 27-35 Site 27.09 – 27.10 Confederation Beach Park

Figure 27-36 Site 27.09 Confederation Beach Park

Figure 27-37 Site 27.10 Confederation Beach Park


Figure 27-46 Site 27.14 Confederation Beach Park


Figure 27-47 Site 27.14 Confederation Beach Park


Figure 27-48 Site 27.15 Confederation Beach Park

Figure 27-49 Site 27.15 Confederation Beach Park

Site 31 Pier 4 Park – Photo Inventory

Figure 31-1 Site 31.01 Pier 4 Park

Figure 31-2 Site 31.01 Pier 4 Park

Figure 31-3 Site 31.01 Pier 4 Park

Figure 31-4 Site 31.02 Pier 4 Park

Figure 31-5 Site 31.03 - 31.04 Pier 4 Park

Figure 31-6 Site 31.05 Pier 4 Park

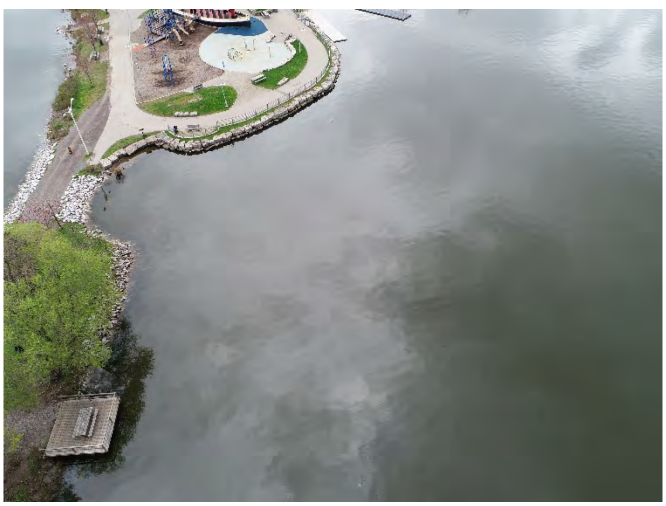


Figure 31-7 Site 31.06 Pier 4 Park

Figure 31-8 Site 31.07 Pier 4 Park

Figure 31-9 Site 31.07 Pier 4 Park

Figure 31-10 Site 31.08 Pier 4 Park

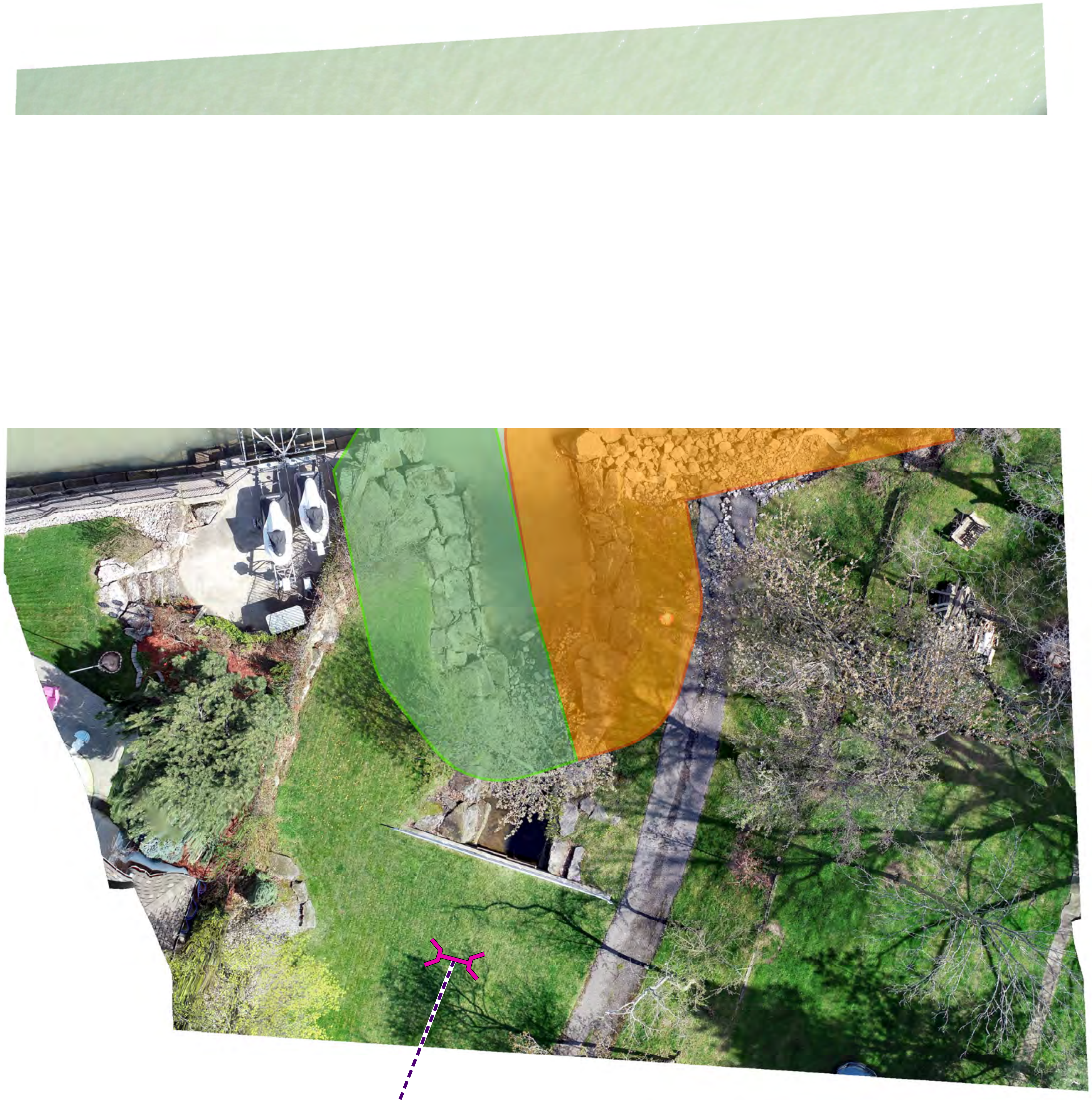
Figure 31-11 Site 31.08 Pier 4 Park

Figure 31-12 Site 31.09 Pier 4 Park

City of Hamilton
2019 Shoreline Assessment

Site 5

Winona Rd



Legend

Outfall Locations

Shoreline Protection Assets

Condition

- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

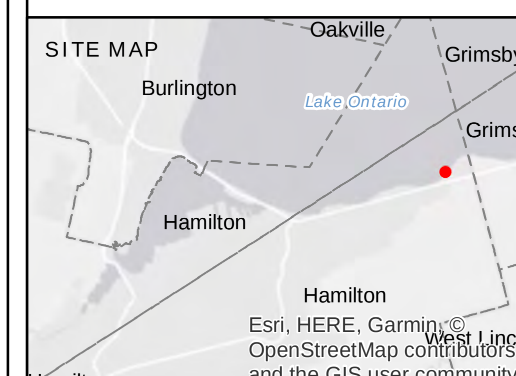
Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

N

0 2 4 6 8
Meters

SITE MAP



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GIS Mapping SNC-Lavalin
September 2019
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City of Hamilton
2019 Shoreline Assessment

Site 11

52 Seabreeze Cr

Legend

Outfall Locations

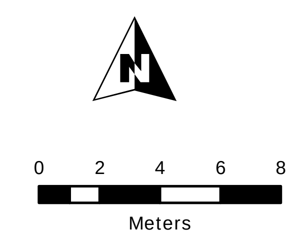
Shoreline Protection Assets

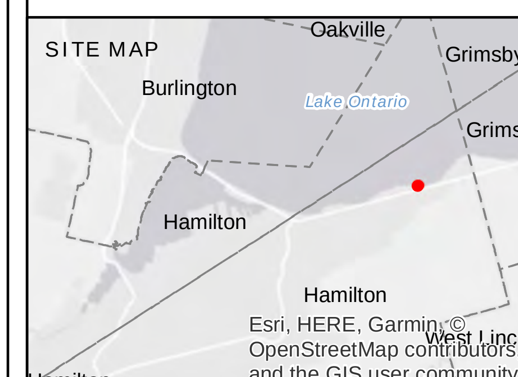
Condition

- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data





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City of Hamilton
2019 Shoreline Assessment

Site 12

Seabreeze Cr (Easement)

Legend

- - - - Outfall Locations

Shoreline Protection Assets

Condition

- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

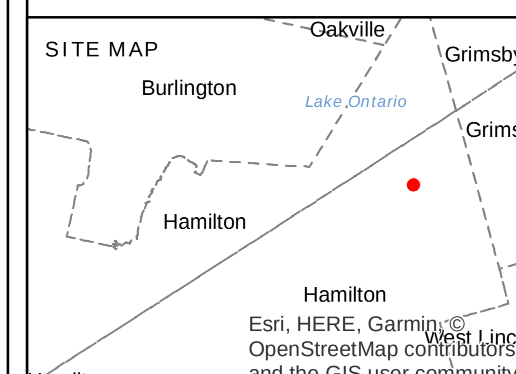
Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

N

0 2 4 6 8
Meters

SITE MAP



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City of Hamilton
2019 Shoreline Assessment

Site 13

Glover Rd

Legend

Outfall Locations

Shoreline Protection Assets

Condition

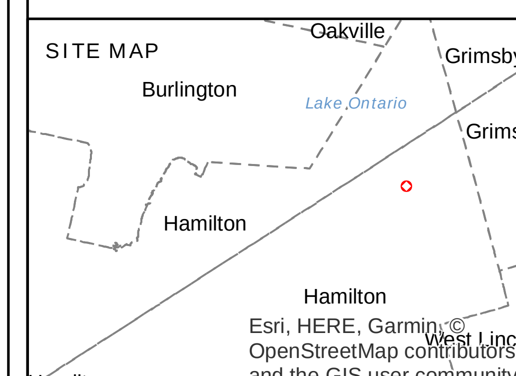
- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

0 2 4 6 8
Meters

SITE MAP



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City of Hamilton
2019 Shoreline Assessment

Site 15

Jones Rd

Legend

Outfall Locations

Shoreline Protection Assets

Condition

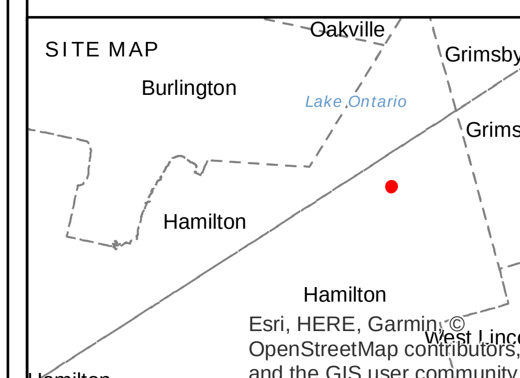
- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

0 2 4 6 8
Meters

SITE MAP



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City of Hamilton
2019 Shoreline Assessment

Site 18

33 Lakeview Drive (SWM)

Legend

Outfall Locations

Shoreline Protection Assets

Condition

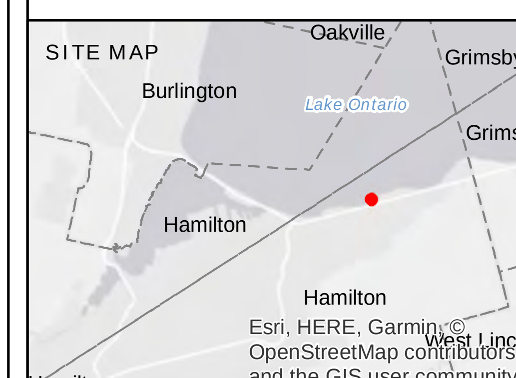
- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

0 2 4 6 8
Meters

SITE MAP



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City of Hamilton
2019 Shoreline Assessment

Site 19

497 & 503 Dewitt Rd

Legend

Outfall Locations

Shoreline Protection Assets

Condition

- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

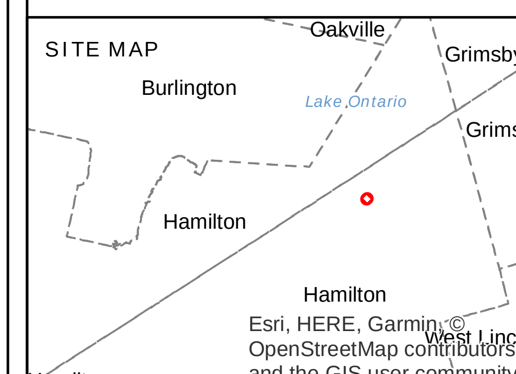
Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

N

0 2 4 6 8
Meters

SITE MAP



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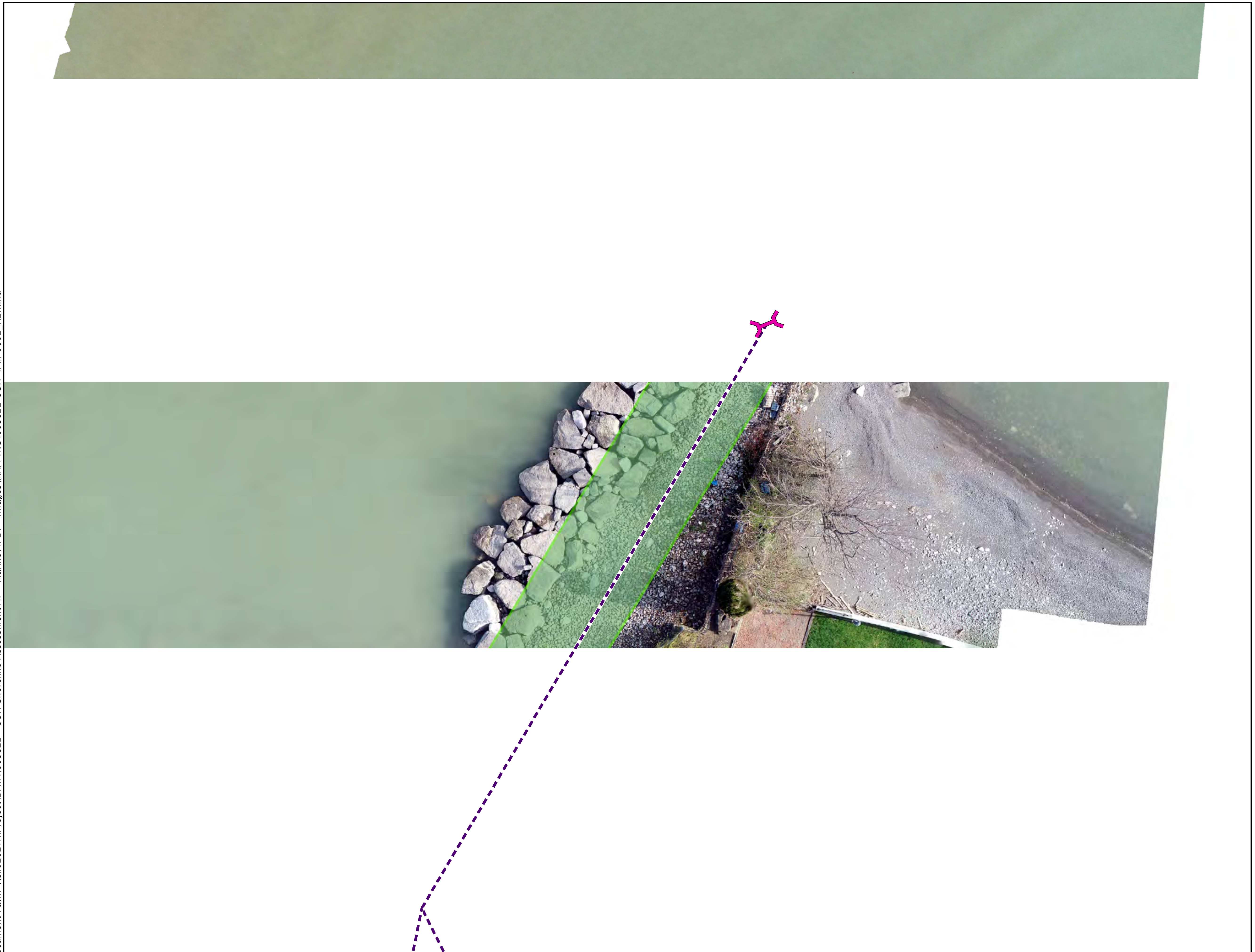
City of Hamilton
2019 Shoreline Assessment

Site 26

655 Grays Rd



Legend

Outfall Locations

Shoreline Protection Assets

Condition

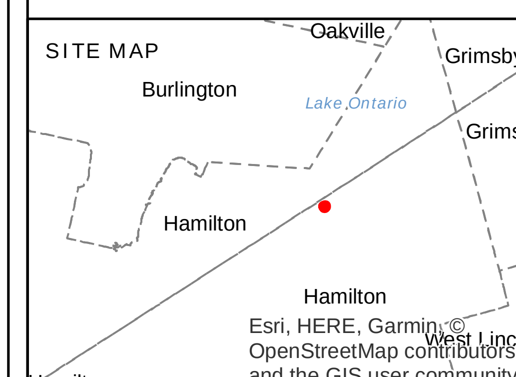
- VGood
- Good
- Fair
- Poor
- VPoor
- Not Rated

Data Sources:

Orthophotos: SNC Lavalin Drone 2019
Average water level during survey = 75.93 m IGLD (Toronto)
Outfall: City of Hamilton GIS Data

0 2 4 6 8
Meters

SITE MAP



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September 2019
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Site 1 Lake Vista Park

Site 4 Wendakee Dr

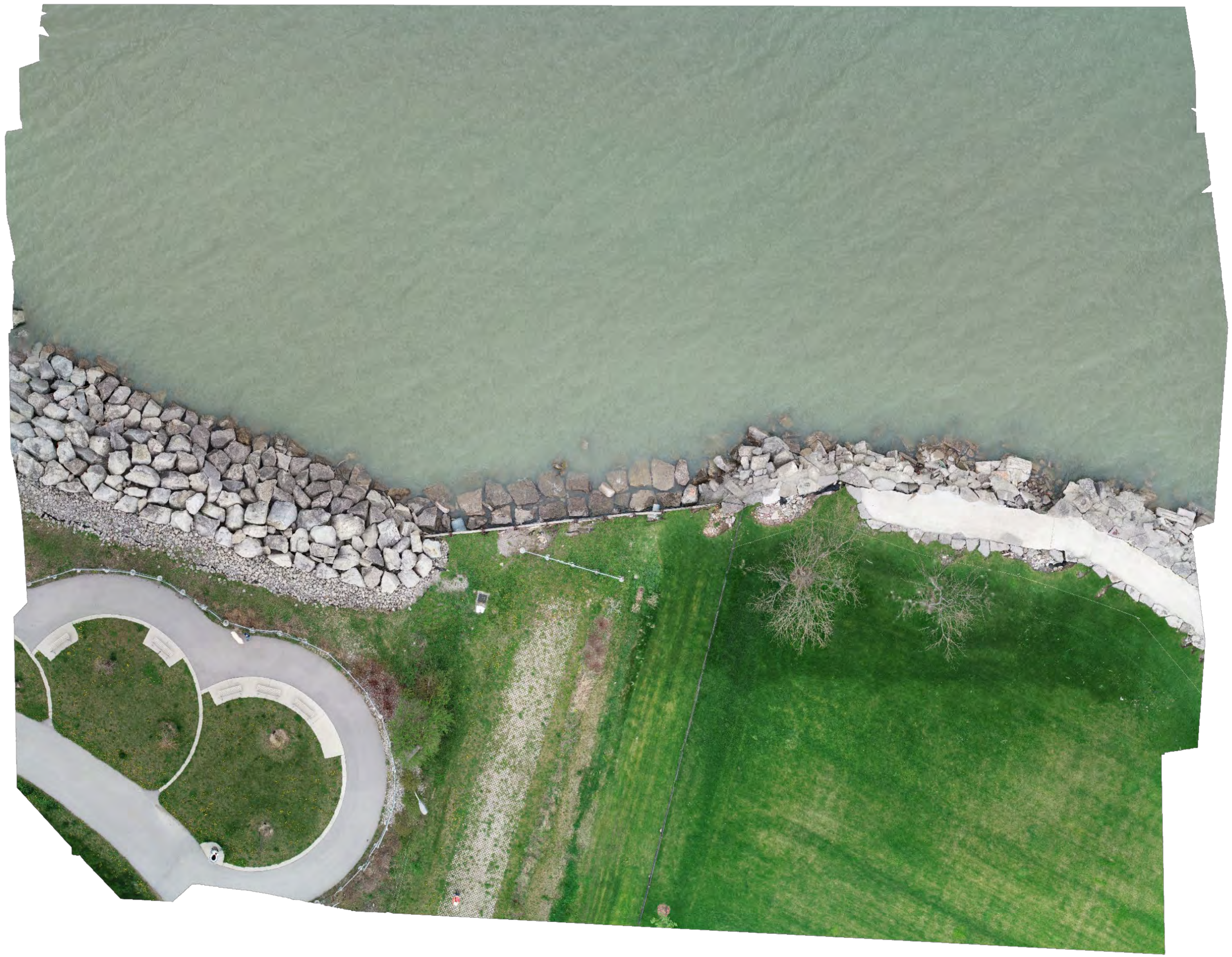
Site 12 Seabreeze Crescent (Easement)

Site 16 Fruitland Rd

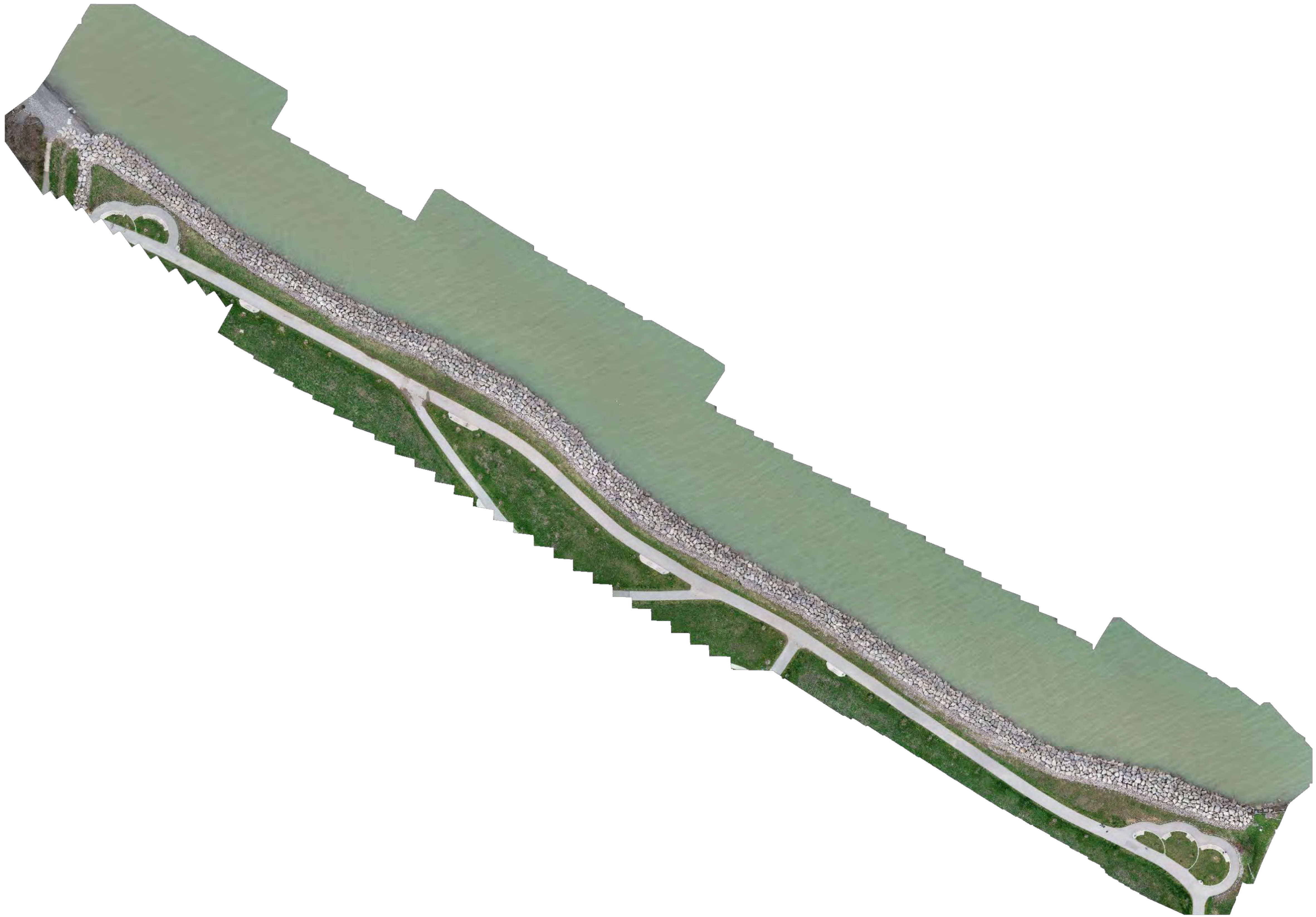
Site 17 2 Frederick Ave, Frederick Parkette

Site 21 1st Private Rd – Excluded

Site 22 Millen Rd Parkette



Site 22B Green Millen Waterfront Trail



Site 23 Frances Ave

Site 24 Green Rd

Site 25 Lawrence P. Sayers Park (39 Lakegate Dr)

Site 30 Macassa Bay Marina

Site 33 Woodland Cemetery